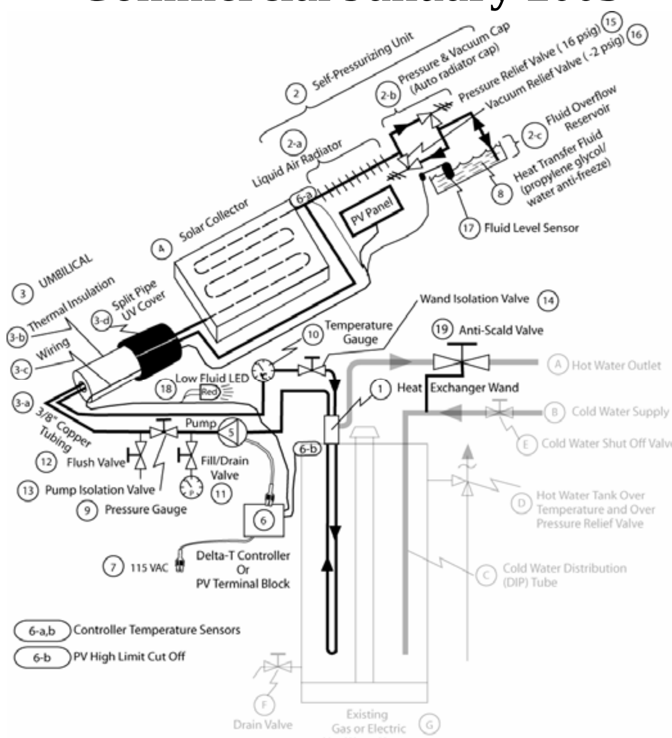
SERVICE MANUAL

THE SOLAR BUTLER 1.0
SOLAR-ASSISTED HOT WATER SYSTEM

- **“Solar Wand” Heat Exchanger**
- **“Sun Blocks” Modular Collectors**
- **Self Pressurizing Unit for Glycol Loop**
- **Stagnation Over-Temp. Protection**
- **Automatic Trapped Air Purging**
- **SRCC OG-300 Certified**
- **ANTI-SCALD Protection**
- **Commercial January 2003**



BUTLER SUN SOLUTIONS
P.O. Box 1666 OR 811 Academy Dr.
Solana Beach, CA 92075
Phone/Fax 858-259-8895, www.butlersunsolutions.com

REVISION LOG

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ACRONYMS

ABS	Acrylonitrile Butadiene Styrene: a tough, light, UV and water-resistant plastic pipe (UV=Ultraviolet light)
ASTM	American Society for Testing Materials
AWG	American Wire Gauge
AWWA	American Water Works Association
DWP	Double Wall with Leak Protection
GPS	Global Positioning System, which measures compass heading and Latitude.
Insolation	Power coming from the sun, 1,000 Watts/m^2 at solar noon. May also be annual daily average which for San Diego is 6.5 kWh/m^2/day.
NPT	United States National Pipe Thread Standard
pH	Log Scale of H+ ion activity, 1 to 6 is Acidic, 7 is neutral, and 8 to 14 is Basic
psi	Pounds Per Square Inch Pressure
psig	Pounds Per Square Inch Gauge or psi above Atmospheric Pressure
psia	Pounds Per Square Inch Absolute
PV	Photovoltaic Panel
SOF	Solar Orientation Factor shows solar system performance as a function of Tilt angle and East-West orientation
Stagnation	The condition where solar energy is being absorbed in the solar collector and there is no fluid flow to remove the heat.
SRCC	Solar Rating and Certification Corporation
UV	Solar Ultraviolet Radiation, which degrades unprotected plastics

1.0 Solar Rating and Certification Corporation (SRCC) Compliance Information

The solar energy system described by this manual, when properly installed and maintained, meets the minimum standards established by the SRCC. This certification does not imply endorsement or warranty of this product by SRCC. Only systems using OG-100 certified collectors listed in **Table 1** will be OG-300 system certifiable.

1.1 Butler Sun Solutions SRCC OG-300 Certified Systems

In the “System Model Number” column of **Table 1**, “PV1” indicates a Photovoltaic powered pump is used to circulate the propylene glycol antifreeze fluid in the solar collector loop. “S1” indicates a 115VAC Delta-T controller is used to power the pump to circulate the propylene glycol antifreeze fluid in the solar collector loop.

Systems have been rated for ACR, Sun Earth and Thermomax solar collectors. Both single tank and dual tank systems have been rated by SRCC. **Figure 1** shows a pictorial view of the system.

Table 1. Certified System Designations

System Model Number	SRCC Certification Number	Collector Area (ft2)	Solar Tank Vol. (gal)	Aux Tank Vol. (gal)	Solar Tank Heat	Aux Tank Heat
BSS-PV1-40Ea	300-2005-005A	24.6	40		Elec.	
BSS-PV1-40Eb	300-2005-005B	20.1	40		Elec.	
BSS-PV1-50Ea	300-2005-005C	32.9	50		Elec.	
BSS-PV1-80Ea	300-2005-005E	40.9	80		Elec.	
BSS-PV1-40Ec	300-2005-005I	40.1	40		Elec.	
BSS-PV1-50Ec	300-2005-005H	40.1	50		Elec.	
BSS-PV1-80Ec	300-2005-005G	40.1	80		Elec.	
BSS-PV1-40Ga	300-2005-006A	24.6	40		Gas	
BSS-PV1-40Gb	300-2005-006B	20.1	40		Gas	
BSS-PV1-50Ga	300-2005-006C	32.9	50		Gas	
BSS-PV1-80Ga	300-2005-006E	40.9	80		Gas	
BSS-PV1-40Gc	300-2005-006I	40.1	40		Gas	
BSS-PV1-50Gc	300-2005-006H	40.1	50		Gas	
BSS-PV1-80Gc	300-2005-006G	40.1	80		Gas	
BSS-S1-80E2a	300-2005-007A	40.1	80	50	Sun	Elec.
BSS-S1-80E2b	300-2005-007B	40.9	80	50	Sun	Elec.
BSS-PV1-80E2a	300-2005-008A	40.1	80	50	Sun	Elec.
BSS-PV1-80E2b	300-2005-008B	40.9	80	50	Sun	Elec.
BSS-S1-80G2a	300-2005-009A	40.1	80	50	Sun	Gas
BSS-S1-80G2b	300-2005-009B	40.9	80	50	Sun	Gas
BSS-PV1-80G2a	300-2005-010A	40.1	80	50	Sun	Gas

BSS-PV1-80G2b	300-2005-010B	40.9	80	50	Sun	Gas

1.1.1 System Name/Designation

Solar Butler 1.0. The system is designated as a Self-Pressurized Closed-Loop Type, Using a Solar Wand Heat Exchanger and Self-Pressurizing Unit

1.1.2 System Type

Low flow-rate (2 Liters per minute, 0.55 Gallons per minute) flat plate solar collector with a self-pressurized, antifreeze filled fluid loop and a double-walled heat exchanger immersed in the existing hot water tank as shown in **Figure 1.1**.

1.1.3 System Description

Glazed, low fluid-flow, flat plate solar collector, with passive liquid-to-air radiator for positive solar collector stagnation protection and double walled, “In-Your-Tank” heat exchanger. The heat transfer system utilizes a pressurized, 16 psig, low volume antifreeze filled fluid loop, similar to automobile cooling systems. The heat transfer fluid is ASTM D5216, propylene glycol, commonly used in automobile radiators. Heat exchange from the collector-heated fluid to the existing hot water tank is accomplished using the screw-in “Solar Wand”. The “Solar Wand” is a double-walled, copper and brass, in-tank heat exchanger of the American Water Works Association (AWWA) Class DWP (Double Wall with leak Protection).

The heat transfer fluid is channeled from the solar collector to the Wand heat exchanger via thin-walled, small diameter (3/8”) copper tubing. The copper tubing is run side-by-side with small plastic standoffs to limit tubing-to-tubing contact. Both tubes together are insulated with closed cell rubber foam insulation to form a collector-to-hot-water-tank umbilical, which includes all electrical and fluid connections. Sensor wiring is attached to the outside of the rubber foam insulation to allow collector temperature sensors to be connected to the controller, or photovoltaic panels to the pump. The circulation pump is a seal-less, low-flow, low-power, low-noise centrifugal pump.

The systems can be controlled in two ways. The first controller type uses a conventional Delta-Temperature controller. The system controller uses temperature sensors on the collector and at the top of the hot water tank to determine when to turn on the circulation pump in the fluid loop to heat the hot water tank. If the hot water tank gets too hot, the controller turns off the circulation pump.

The second control configuration uses a photovoltaic panel to drive a 12VDC circulation pump, so when the sun is out the pump runs to circulate the heat transfer fluid. A cut off switch is used so if the hot water tank gets too hot the pump will be shut off, even if the

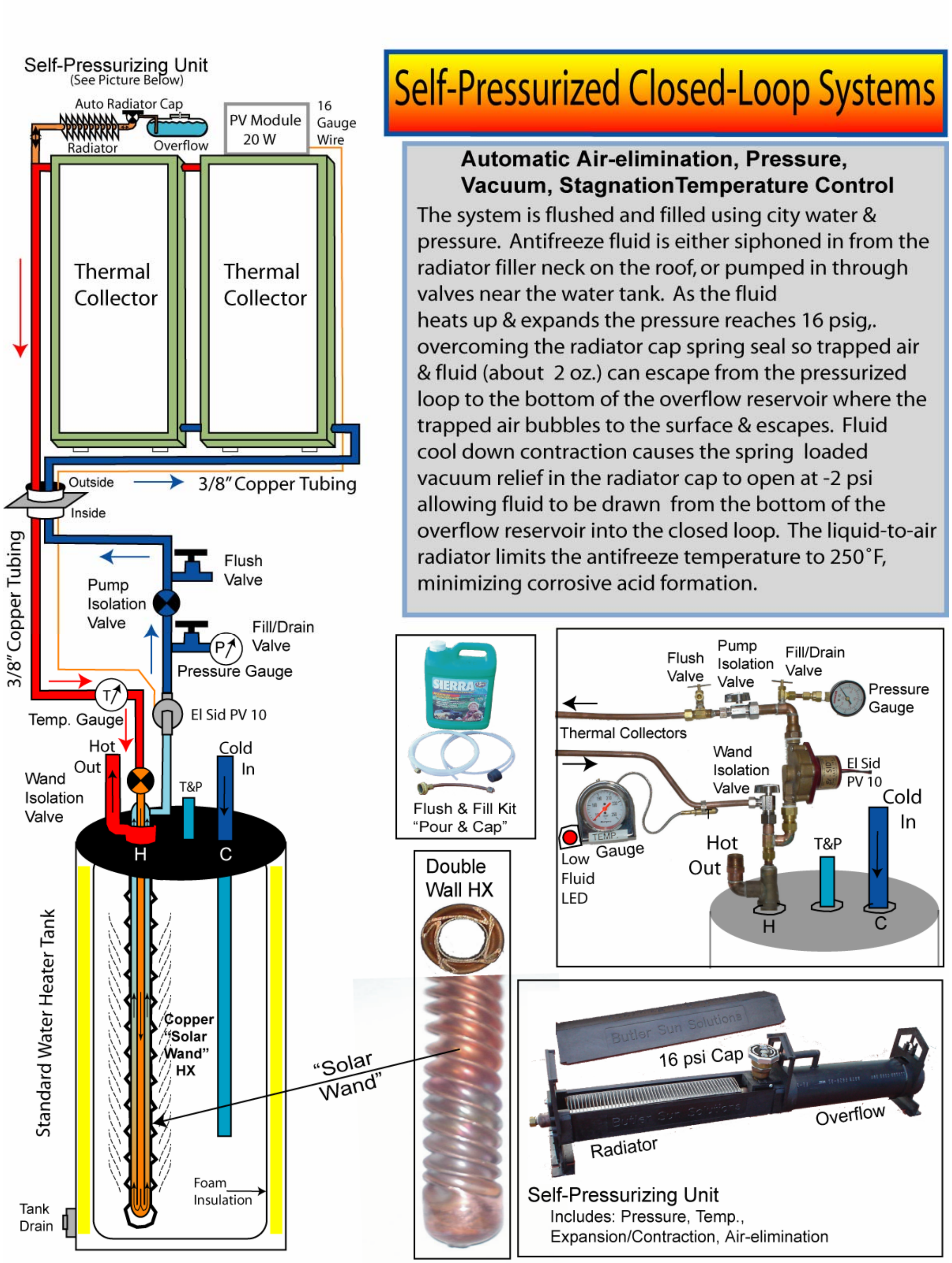


Figure 1.1 Pictorial View of Solar Butler 1.0 System

sun is out. This system requires no outside source of power but costs a little more up front.

The solar collection and delivery parts of the hot water system are simple, using about the same amount of copper as your automobile radiator, roughly 35 pounds. This allows the system to be low in cost. Potable water sees only copper, tin-based ("lead-free") solder and silver solder on the solar wand. The antifreeze heat transfer fluid is contained in materials which should resist corrosion for at least 35 years or more, with low maintenance: copper tubing, stainless steel pump, and brass fittings. Because of the double wall wand heat exchanger antifreeze cannot leak into the potable water supply.

The solar heat storage is accomplished with two different water tank storage configurations, Solar Assisted Hot Water (Solar Assist. and Solar Augmented Hot Water (Solar Augment). Solar Assist uses your existing hot water tank to store the solar heated water. The Solar Assist configuration is shown in **Figure 1.2**. Solar Assist is used where there is not room for a second tank, or the existing tank is large (60-80 gallons).

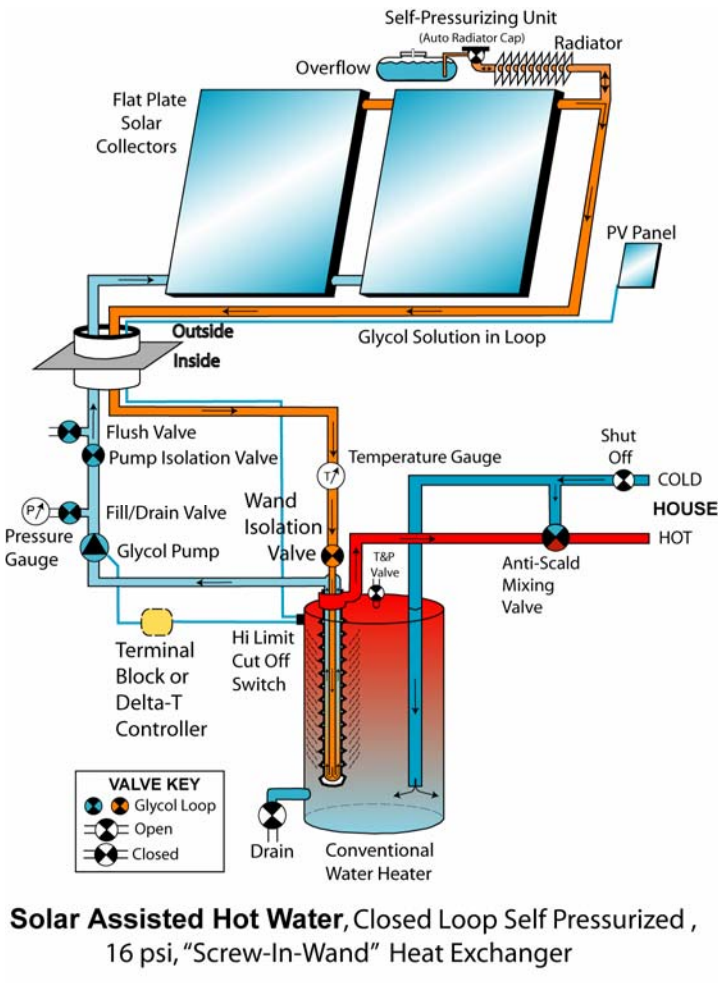


Figure 1.2 Solar Assisted Hot Water System, Single Tank Installation

The Solar Assist configuration does not deliver as much solar hot water as the Solar Augment, because both solar and electricity or gas are heating the water in the single

existing hot water tank. Because the auxiliary heater is always active, the water in the tank never goes below the set point of the auxiliary heater except temporarily during times of heavy water usage. Thus the solar system can only contribute heat above the set point of the auxiliary heater.

Solar Augment adds an additional solar storage tank between the incoming cold water and the existing hot water tank or tankless water heater. The Solar Augment configuration is shown in **Figures 1.3 and 1.4**. The Solar Augment configuration provides more solar heated water to the residence, because the solar input heats the low temperature water in the solar preheat tank, and only electricity or gas are used to heat the existing tank or tankless water heater. The cost of the added tank must be balanced against the added solar hot water produced. Solar Augment is used when there is room for a new solar storage tank and the existing tank is small (30-40 gallons) or a tankless water heater is used.

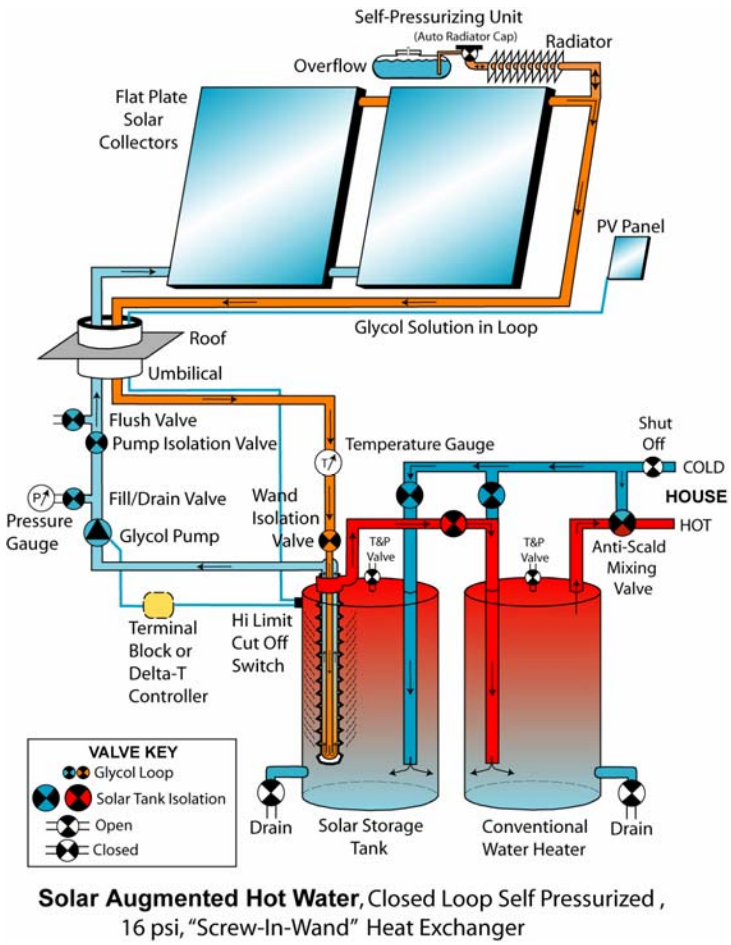


Figure 1.3 Solar Augmented Hot Water System, Two Tank Installation

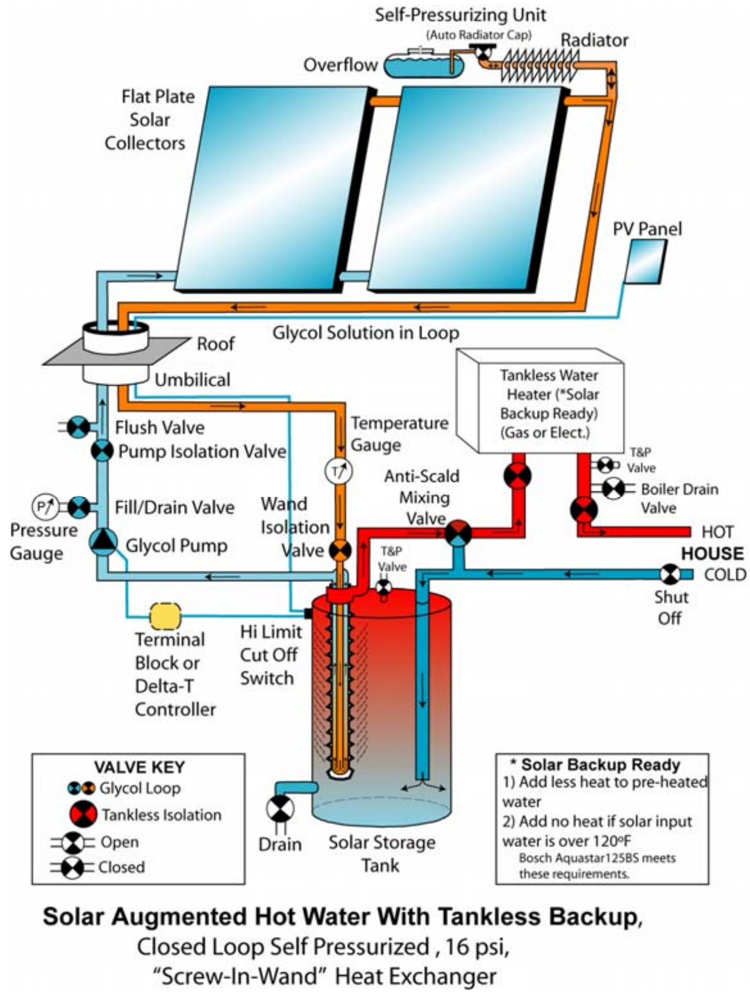


Figure 1.4 Solar Augmented Hot Water System with tankless water heater backing up the solar storage tank

1.1.4 <u>Solar Collector</u>

Single-glazed glass, selective absorber plate, aluminum foil-faced poly-isocyanurate foam insulation and aluminum frame, with provision for: 1.) Flashing into the roof; 2.) Mounting parallel over the existing roof; and 3.) Mounting at higher than roof pitch angles.

1.1.5 <u>Water Tank</u>

The home's existing gas or electric hot water tank is used as the storage tank for the system. The proper collector area must be selected to match the existing hot water tank's capacity of 40, 60 or 80 gallons.

1.1.6 <u>Collector Area</u>

The solar collector area needed depends on where the system will be located. The OG-300 rating provides an estimate of system performance. In good solar areas of the Southwest, the collector area in square feet should be roughly half the tank capacity in gallons; in poor solar locations, the optimum ratio approaches one square foot of collector per gallon of storage. So, for example a 40 gallon tank would require 20 square feet of solar collector in Arizona, and 40 square feet in Maine.

1.1.7 Liquid-to-Air Heat Exchanger

The over-temperature radiator has about 0.16 m^2 (1.8 square feet) of surface area capable of protecting the solar system from excessive boil over and fluid loss caused by stagnation. Stagnation describes the condition where solar energy is being absorbed in the solar collector and there is no fluid flow to remove the heat. In this case the fluid in the solar collector will boil at 16 psig, creating 124^{o}C (256^{o}F) steam. The steam makes its way out of the top of the solar collector and toward the radiator cap. However it must pass through the liquid-to-air heat exchanger first. The differential temperature between the outside air and the steam causes heat to be removed from the steam and be delivered to the outside air. This heat loss to the surrounding air condenses most of the steam back to water which finds its way back to the solar collector. The small amount of steam that blows past the radiator cap and enters the overflow reservoir is condensed as it bubbles through the fluid in the reservoir and is held there as liquid for reintroduction into the system upon cooling.

1.1.8 Wand Antifreeze to Potable Water Heat Exchanger

The Standard 1.2 m (48 inch) “Long Wand” has about 0.18 m^2 (2 square feet) of heat transfer area inside the hot water tank. The Standard 0.96 m (38 inch) ”Short Wand” has about 0.14 m^2 (1.6 square feet) of heat transfer area inside the hot water tank. The Wand has a small diameter center tube, which delivers the hot collector fluid to the bottom of the Wand, near the bottom of the hot water tank. This tube is enclosed in second tube (the first wall) and the hot fluid flows up the annular space between the inlet tube and second tube. A third tube (second wall) is spiral collapsed on the second tube, making mechanical contact for heat transfer over about 60% of the wall and leaving an air space. The third tube is vented on top of the wand, so any fluid between the second and third tubes is vented to atmosphere. This assembly is inserted in the hot water tank by being screwed into the hot water outlet port.

The wand is designed to meet the requirements of the AWWA Class DWP (Double Wall with leak Protection). Class DWP “Provides two distinct walls which separate the transfer medium from the potable water and a path to atmosphere. Failure of either wall is indicated by visual leakage of the transfer medium or potable water and indicates a failure of the heat exchanger”. The DWP type provides a higher degree of protection than the SW (Single Wall with no leak detection) or DW (Double wall with no leak detection).

The solar Wand is designed so a single failure of any fluid barrier will not cause a cross connection or permit back siphoning of heat transfer fluid into the potable water system.

Any barrier which fails allows the discharge of exchanger fluid and/or potable water to the atmosphere at a location visible to the operator or owner.

1.1.9 Freeze Tolerance

Freeze Tolerance Limits: The system is designed to operate to -32°C (-26°F), with the normal 50/50 propylene glycol-water mixture. Below that temperature slush will form which will not circulate, but will not damage the collectors until -48°C (-54°F). To operate at -48°C (-54°F) a 60% propylene glycol-40% water mixture would be required.

Minimum Operating Temperatures:

- Propylene glycol-water 50/50 -32°C (-26°F)
- Propylene glycol-water 60/40 -48°C (-54°F)

1.1. 10 Boiling Tolerance

The system is pressurized to 16 pounds above atmospheric pressure (16 psig) during operation using a standard automobile radiator cap. The antifreeze mixtures have the following boiling points:

- Propylene glycol-water 50/50 124°C (256°F) @ 16 psig,
- Propylene glycol-water 60/40 127°C (261°F) @ 16 psig,.

Boiling activates the liquid-to-air radiator, which limits collector boiling temperature by transferring solar heated steam from the solar collector to the radiator where it is convected to the surrounding air. A small amount of liquid will be expelled from the system, then boiling and the condensing of steam forms a heat pipe between the solar collector and the liquid-to-air radiator. This heat pipe action limits the temperature in the collector to the fluid boiling point listed above, since the pressure is fixed at 16 pounds above atmospheric pressure. See **Figure 2.4** for details.

1.1.11 Toxicity

The recommended heat exchanger fluid, propylene glycol and water, is non-flammable and non-toxic. Propylene glycol is an American Water Works Association (AWAA) Class II fluid. This means that it has a Gosselin toxicity rating below 1. Class II material are considered non-potable and may be objectionable, but not dangerous to health. A typical system contains from one to two gallons of fluid. It should be changed at 5 year intervals over the life of the system. Proper disposal is required. Propylene glycol-water mixtures are recycled by service stations and auto stores. Consult your local retailer of antifreeze for proper disposal in your area. Leakage or small spills can be absorbed with paper towels or “kitty litter” and disposed of in the trash.

1.1.12 Contamination:

The Wand heat exchanger meets the American Water Works Association, Cross Contamination Control's highest level of protection. The Wand is an anti-siphoning device. The space between the two heat exchanger wall, potable water and heat transfer fluid is at atmospheric pressure. The potable water is usually above 50 psig and hence will leak out of the tank. The heat transfer loop is pressurized by the fluid head above the tank, usually 10 psig plus 16 psig, the cap pressure. Hence heat transfer fluid pressure at the tank gauge would be about 26 psig, so fluid would leak out to atmosphere, and provide maximum anti-siphon protection. If the passages to atmosphere were all blocked, by accident, and both heat exchanger walls were breached, potable water, usually greater than 50 psig, would flow into the collector loop and out the pressure cap. The leak on the roof would soon be spotted and the system repaired without contamination of potable water. **CAUTION: FOR ROOFS HIGHER THAN 66 FEET, THE COLLECTOR LOOP PRESSURE AT THE WATER TANK COULD EXCEED 50 PSI. THE DOUBLE WALL ISOLATION PASSAGES TO ATMOSPHERE MUST BE CHECKED ANNUALLY TO ASSURE NO BLOCKAGE.**

1.1.13 Leakage

Leakage of the heat exchange fluid is not a major problem because there is usually less than two gallons total. Leaks can be cleaned up with absorbent towels or "kitty litter" and disposed of in the trash.

Leakage of potable water would only occur at the solar Wand. There it would come out the small opening in the top of the Wand. It would then run down the side of the water tank into the drip pan or onto the floor. It would be visually detected. This would signal a damaged Wand heat exchanger which would need to be replaced. To restore hot water use until a new Wand is installed, the damaged Wand should be removed and the hot water pipe reconnected to the hot water tank, just as it was before the original Wand was installed. **HINT: SAVE THE ORIGINAL HOT WATER CONNECTIONS TO THE HOUSE, DO NOT DISCARD.**

1.1.14 Hazards:

Hot pressurized heat exchanger fluid can scald and/or flash to steam, which will also scald. **CAUTION: DO NOT LOOSEN ANY CONNECTIONS WHILE THE SYSTEM IS RUNNING & DO NOT REMOVE THE RADIATOR CAP WHILE THE SYSTEM IS RUNNING.**

Electrical connections for the thermistors are all low voltage and protected by a fuse. The controller plugs into the wall and grounds the pump. Be sure that three wire grounded outlets are used and don't try to fix the control box. Unplug and call for service. A ground fault interrupted outlet is required to minimize the potential electrical shock hazard.

Water from the hot water tank can scald. When the solar collector is installed an Anti-Scald valve must be installed on the hot water tank outlet to allow the solar system to be SRCC OG-300 Certified. The Anti-Scald valve must meet new housing code standards.

2.0 System Operation and Component Functions

The complete system is shown in **Figure 2.0.** The parts that comprise the Solar Butler 1.0 system and need to be installed in your house are shown as dark in the line drawing. The parts that are already in your home are shown as light, or faded, in the line drawing. This allows the Solar Butler 1.0 system to be less complex. The interface between your existing hot water system and the Solar Butler 1.0 is the heat exchanger wand, (1), Patent No. US 6,837,303 B2 issued Jan 4, 2005.

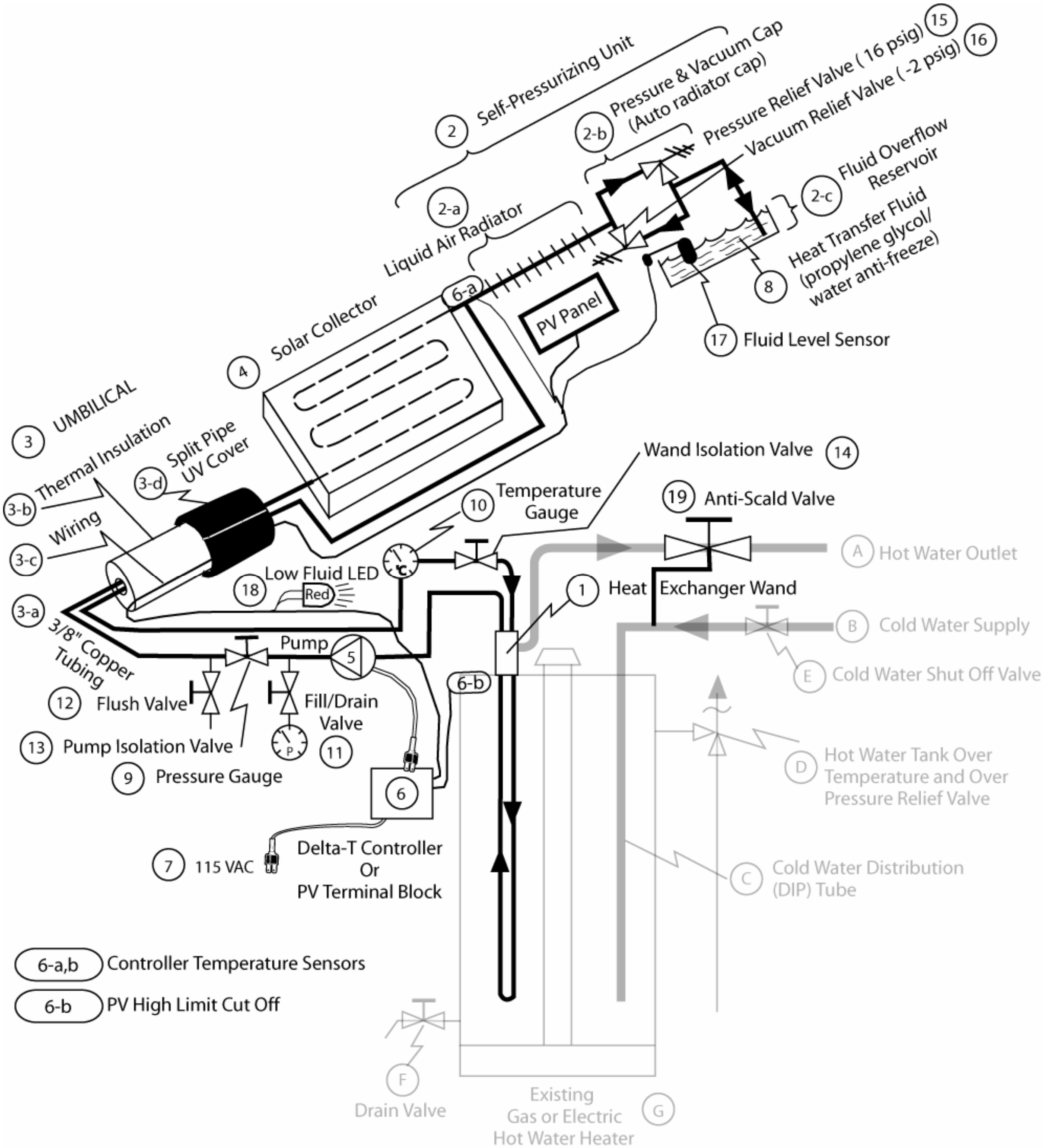


Figure 2.0 System Schematic Diagram

2.1 Solar Wand in-tank heat exchanger:

Double-walled heat exchanger, constructed of copper and brass, which screws in the existing hot water tank's hot water outlet. AWWA Class DWP (Double Wall with leak Protection), "Provides two distinct walls, which separate the transfer medium from the potable water and a path to atmosphere. Failure of either wall is indicated by visual leakage (*on the top of the hot water tank, coming from the annular wand vent space.*) Leakage of the transfer medium or potable water and indicates a failure of the heat exchanger". The DWP type provides a higher degree of protection than the SW (Single Wall with no leak detection) or DW (Double wall with no leak detection).

The solar Wand, a double-walled heat exchanger, is designed so a single failure of any fluid barrier will not cause a cross connection or permit back siphoning of heat transfer fluid into the potable water system. Any barrier that fails allows the discharge of exchanger fluid and/or potable water to the atmosphere at a location visible to the operator or owner. **Figure 2.1** shows a cut away view of a "Solar Wand".

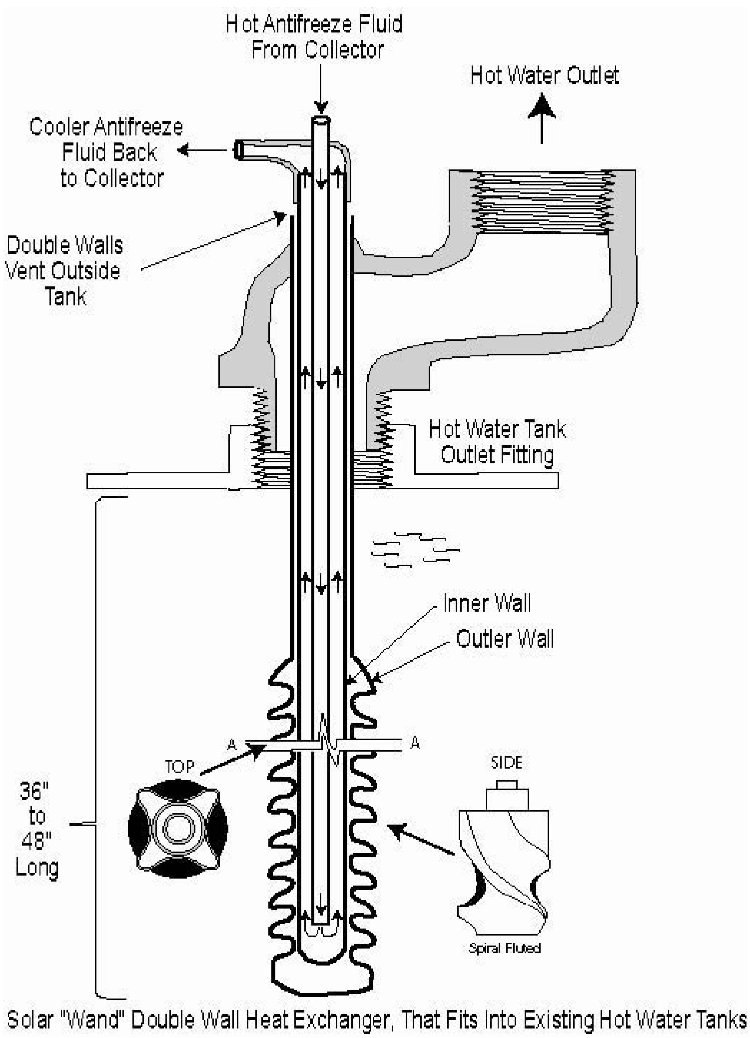


Figure 2.1 "Solar Wand" Cut Away View

The solar Wand provides approximately 0.2 m^2 (2 Square feet) of copper heat transfer surface in your hot water tank. The spiral flutes add heat transfer surface area while still allowing the Wand to be inserted into the hot water tank through the standard ¾ inch National Pipe Thread (NPT) female **HOT WATER OUTLET** port on the top of the hot water tank.

WARNING: DO NOT TRY TO INSTALL THE WAND IN THE COLD WATER INLET OF THE HOT WATER TANK. THE COLD WATER INLET FITTING IS SMALLER IN DIAMETER TO HOLD THE DIP TUBE NEEDED TO DELIVER COLD WATER TO THE BOTTOM OF THE TANK.

NOTICE: IT HAS COME TO OUR ATTENTION THAT SOME HOT WATER TANKS HAVE NECKED DOWN REGIONS BELOW THE THREADS ON THE HOT WATER OUTLETS. THIS REQUIRES THAT THE NECKED DOWN REGION BE FILED OFF, BEFORE THE WAND CAN BE INSTALLED, SEE FIGURE 2.2.

All that is needed to install the Wand is Teflon Plumber's Tape and a 12" Pipe wrench.

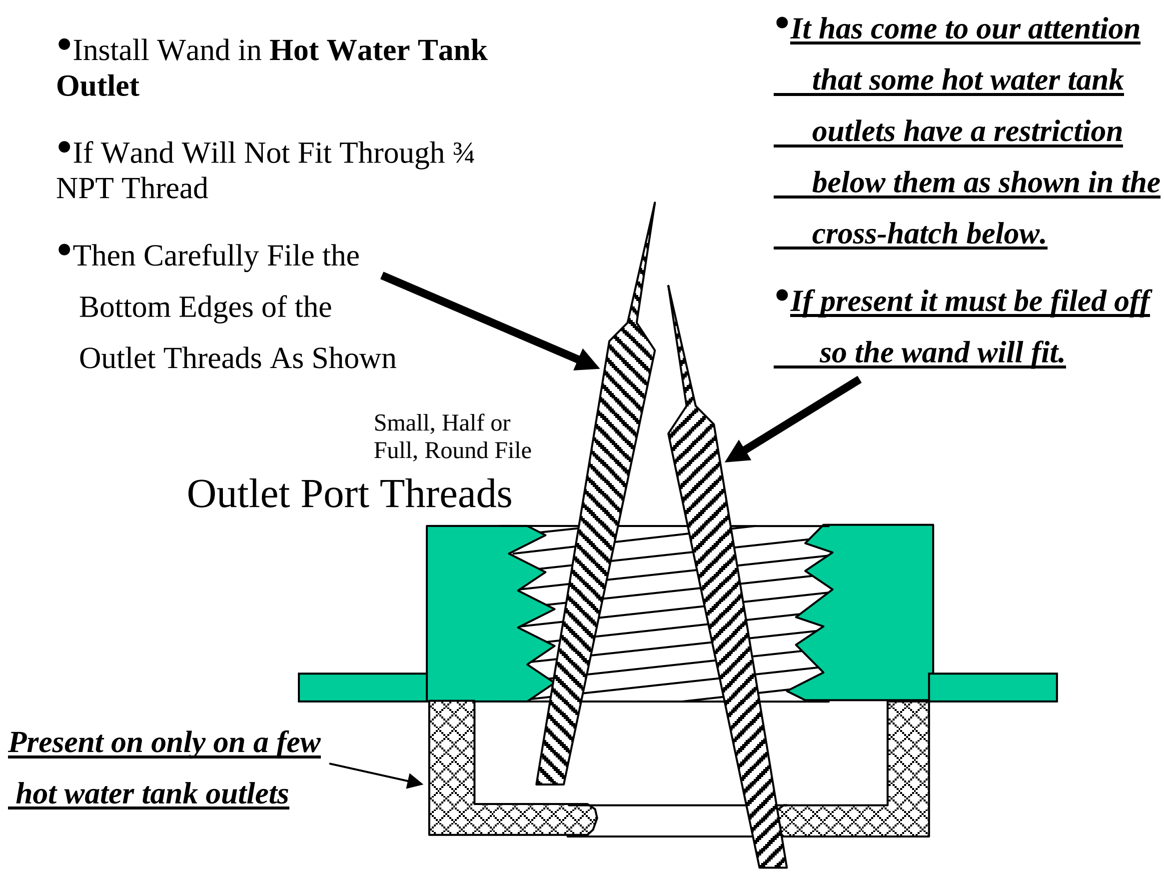


Figure 2.2 Solar Wand Installation Note

NOTICE: IT HAS COME TO OUR ATTENTION THAT SOME HOT WATER TANKS MADE BY THE BRADFORD-WHITE COMPANY HAVE THE SACRIFICIAL ANODE ATTACHED BELOW THE HOT WATER OUTLET. IF YOU HAVE ONE OF THESE TANKS FOLLOW THE INSTRUCTIONS IN FIGURE 2.3.

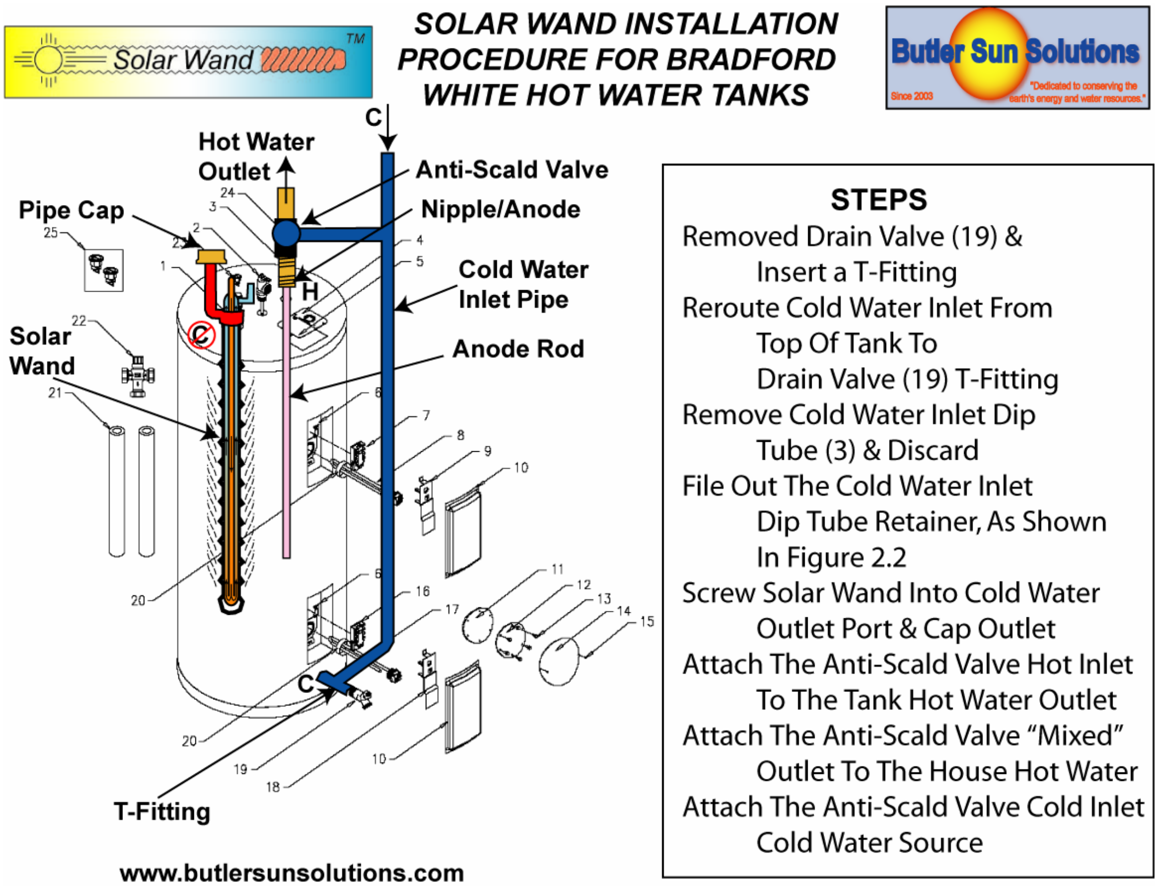


Figure 2.3 Wand Installations in Bradford-White Hot Water Tanks.

2.2 Self-Pressurizing Unit

The Self-Pressurizing Unit consists of a liquid-to-air radiator, a radiator cap with a 16 psi pressure relief and a -2 psi vacuum relief in parallel and a fluid recovery reservoir. The Self-Pressurizing Unit operating states are shown in **Figure 2.4**. The Self-Pressurizing Unit:

1) Accommodates fluid thermal expansion by regulating the closed loop system pressure and allowing fluid to escape to the overflow reservoir;

2) Accommodates fluid thermal contraction by regulating the closed loop system vacuum and allowing fluid to re-enter the closed loop from the overflow reservoir;

3) Automatically eliminates air and non- condensable trapped gases from the closed loop;

4) Limits the temperature of the glycol/water mixture in the closed loop to about 250°F, by condensing steam from the solar collectors in the liquid(steam)-to-air radiator.

Items 3 and 4 above increase system life by limiting corrosion causing oxygen from the closed loop, and keeping the antifreeze temperature below the point where rapid antifreeze acidification occurs.

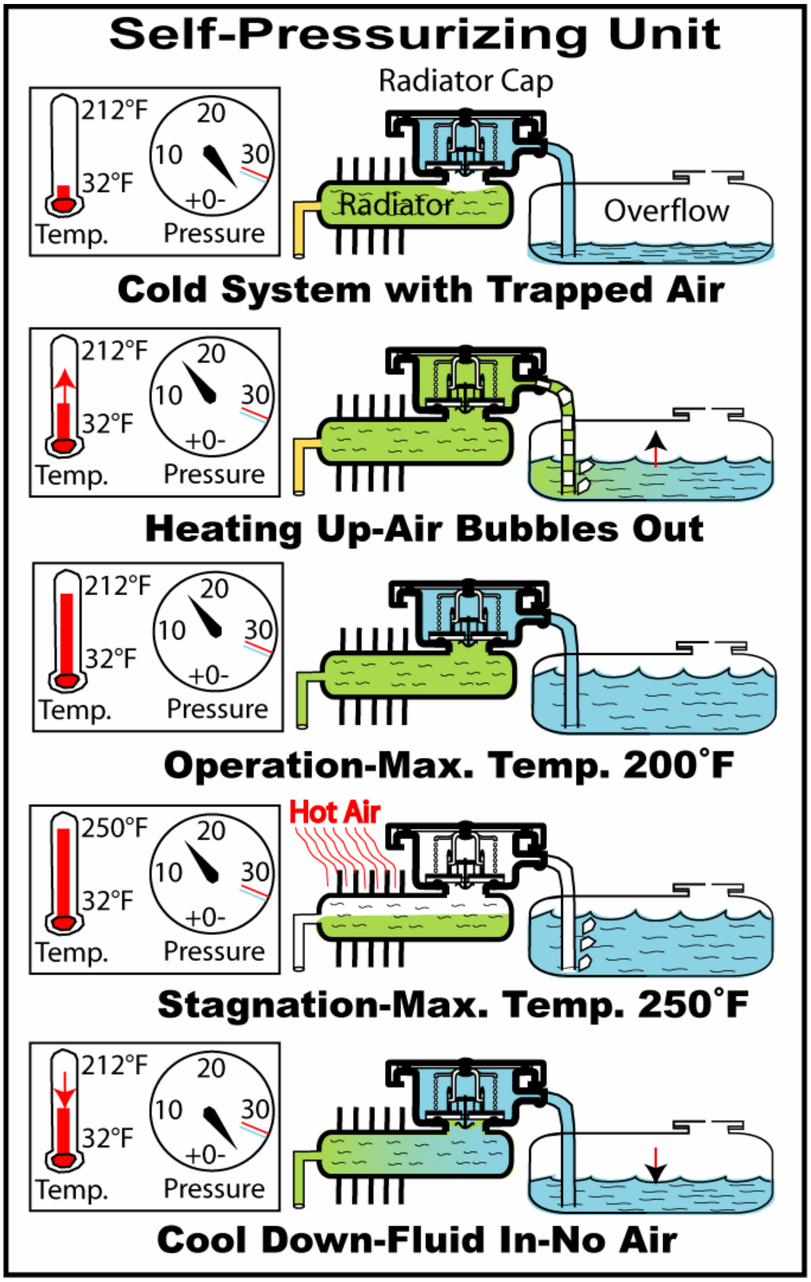


Figure 2.4 Operating States of Self-Pressurizing Unit

2.2.1 Liquid-to-Air Radiator for Over-temperature Protection

The liquid-to-air heat exchanger is a pipe with attached fins to allow the air to remove heat from the pipe efficiently, like the finned pipes used in hydronic heating in houses. If the sun is out and circulation of fluid stops, the collector will begin to boil. This can happen if the storage tank top temperature exceeds the 185^{o}F set point on a sunny day and the fluid circulation pump shuts off until the tank needs more solar heat. Fluid circulation stoppage with the sun out could also be caused by other events such as a pump or controller failure, or a power outage or plugged pipe.

The system is designed to protect itself from damage if fluid circulation stops. It does this by limiting the temperature and pressure in the collector. When the collector starts to boil, a small amount of fluid is pushed out of the collector past the Pressure & Vacuum Radiator Cap (2-b) at 16 psig into the coolant recovery reservoir. As the fluid in the collector continues to boil, the steam bubbles must pass through the liquid-to-air heat exchanger to get to the Pressure & Vacuum Radiator Cap (2-b). Outside air cools the fluid in the liquid-to-air heat exchanger, so the steam bubbles condense and do not escape from the system or force more fluid out. The liquid-to-air heat exchanger is sized to dissipate most of the heat energy the sun can put into the collector.

The boiling action and steam condensation in the liquid-to-air heat exchanger keeps the collector temperature near 124^{o}C (256^{o}F). This is well below the 260^{o}C (500^{o}F) glycol-water degradation temperature, where strong acids form which can corrode through the copper plumbing. This heat-pipe based collector protection system works the same way a car radiator protects the car’s engine from overheating. When circulation is restored, the system runs normally, and when the system cools down at night, the fluid (with no air) is drawn back into the system via the vacuum recovery valve on the Pressure & Vacuum Radiator Cap (2-b). Preventing excessive temperature in the antifreeze allows for a preventive maintenance five-year replacement interval. With pH checking every 5 years systems have run over 20 years without an antifreeze change.

2.2.2 Bladder Expansion Tank Thermal Expansion Management

In contrast to the Butler Sun Solutions self pressurizing system, another type of closed loop antifreeze system in common use today is based upon a bladder lined expansion tank. The bladder expansion tank systems do not have automatic air elimination or over-temperature protection. These expansion tanks are commonly used in hydronic heating systems and have glycol/water on one side of the bladder and pressurized air on the other side, as shown in **Figure 2.5**. As the heat transfer fluid expands on heating, the bladder is pushed into the air space, this raises the pressure slightly, because the air space is large compared to the total volume of fluid expansion. When the fluid cools off the bladder will contract, pushed by the compressed air. Since the system is closed, any trapped air must be vented by manual valves, or special air purging valves. If heat transfer fluid flow stops, boiling in the solar collectors will raise the pressure in the closed system until the 75 psi pressure relief valve is activated. At this point the antifreeze will experience temperatures over 177^{o}C (350^{o}F) . These temperatures are high enough to cause the normally basic (pH 8.6) glycol to break down and form a strong acid (pH 5.0). The glycol turns from light green in color to dark brown, smells burned and begins to corrode pin holes in the copper tubing containing it. If the antifreeze sees these temperatures, it must be changed immediately. Most system owners are not alerted to the pressure relief

valve releasing. Hence they must be alert for the system circulation stopping due to power outages, controller or pump failures. When these conditions are detected the system owner must check the pH of the antifreeze and replace it immediately if it has become acidic.

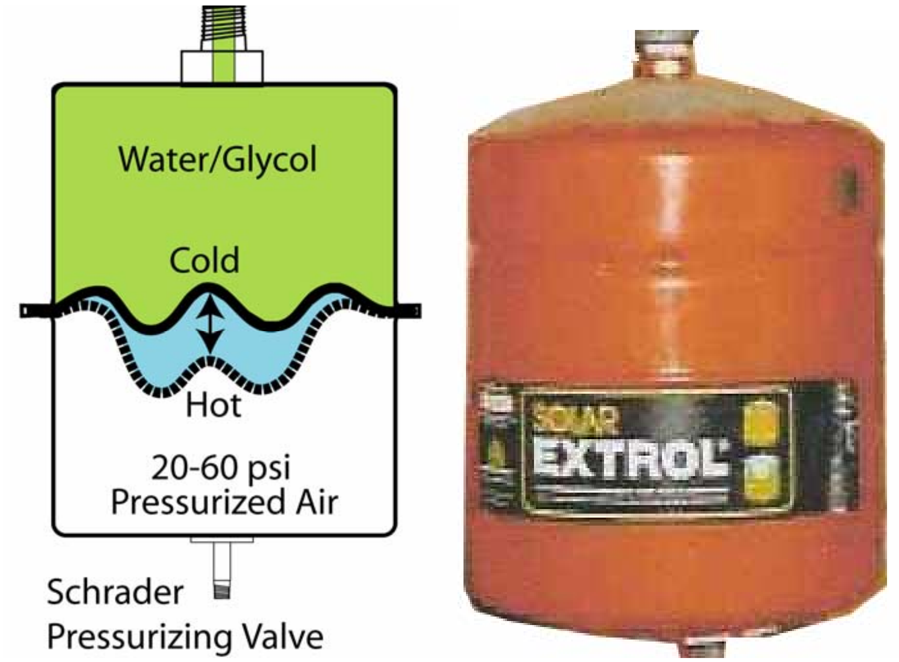


Figure 2.5 Closed System Air Bladder Fluid Expansion Tank

The pressure temperature diagrams of the Self Pressurizing System and Closed Air-Bladder Pressurized System are graphed in **Figure 2.6**. The Self Pressurizing System curve, shown in pink and yellow, shows how the liquid-to-air radiator dissipates the heat from the solar collector, when fluid flow stops and automatically keeps the glycol in the safe operating temperature range to keep acids from forming.

The Closed Air-Bladder Pressurized System curve shown in dark blue in **Figure 2.6** shows how the solar collector itself dissipates the heat when fluid flow stops and may allow the glycol to go above the safe operating temperature range and allow acids to form. Collector overheating can cause early system failure due to copper corrosion, so sizing the solar collectors to match the size of the solar hot water storage tank is very critical to the life of Closed Air-Bladder Pressurized Systems. For example, increasing the square feet of solar collector for the storage tank volume in gallons, should only be done in extremely cold climates, or where collectors are not oriented and tilted South.

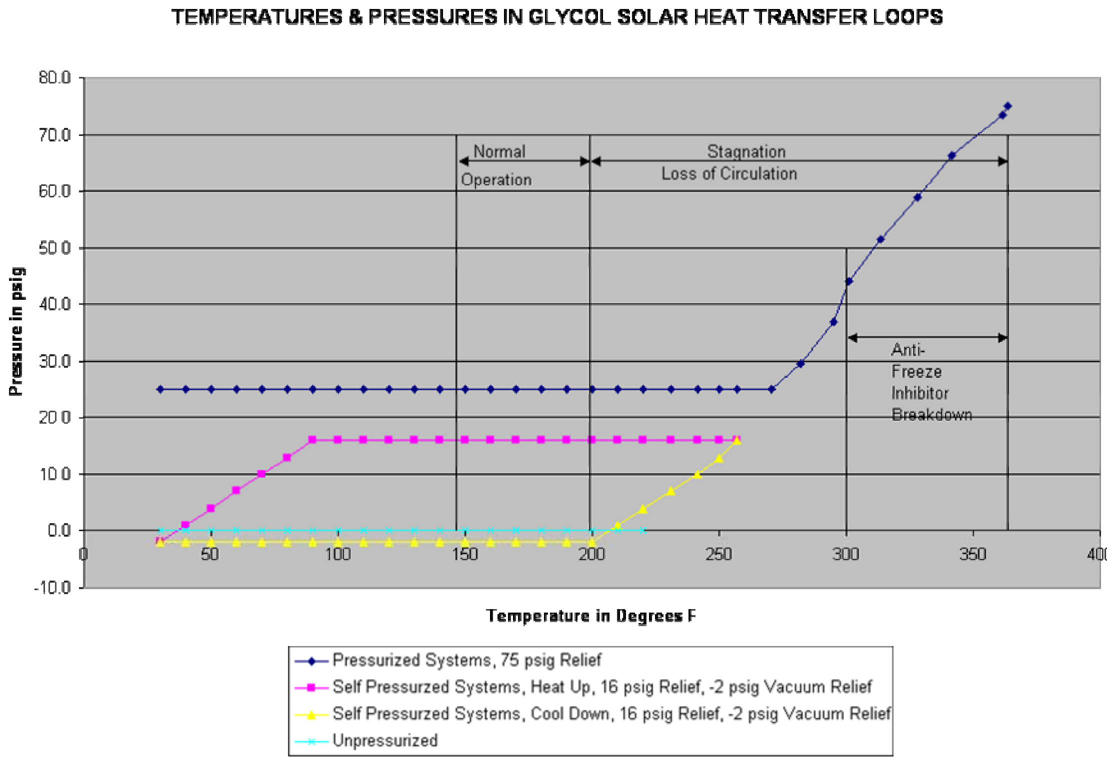


Figure 2.6 Glycol Temperature & Pressure of Self-Pressurized and Bladder Pressurized Close Loop Systems.

2.2.3 <u>Pressure & Vacuum Cap for fluid loop</u>
The system uses a standard automobile radiator fluid filler neck and standard automobile radiator cap, designated as “16 Pound, Non-Vented”. The cap maintains 16 psig of pressure above atmosphere. If the pressure exceeds that value it releases liquid or steam to the fluid overflow reservoir. When the system cools off and goes sub-atmospheric, the vacuum recovery valve built into the cap automatically allows fluid in the coolant recovery reservoir to go back into the fluid loop. You never notice this taking place, but it happens in your automobile every time it cools off and then heats up again, see **Figure 2.7**.

“Non-Vented” means that air is not admitted to the heat transfer system. Fluid thermal expansion pushes fluid and air out of the system after the radiator cap has been opened to admitting air when the system is filled. As the fluid loop cools off, the thermal contraction the antifreeze-water mixture causes, only the antifreeze-water mixture to be drawn back in from the overflow. This action over a few heat up and cool down cycles removes all air from the fluid loop and keeps it out.. This is important because the presence of air in the fluid loop accelerates corrosion and promotes acid formation. You can tell if a radiator cap is vented or non-vented by holding it above your head and looking at the small round disk in the center of the bottom, sealing end of the cap. If it is falling down, it is vented. If a small spring force is holding it in place it is non-vented. Figure 2.7 includes a cross-section view of a typical non-vented radiator cap.
CAUTION: USE ONLY NON-VENTED RADIATOR CAPS ON THIS SYSTEM.

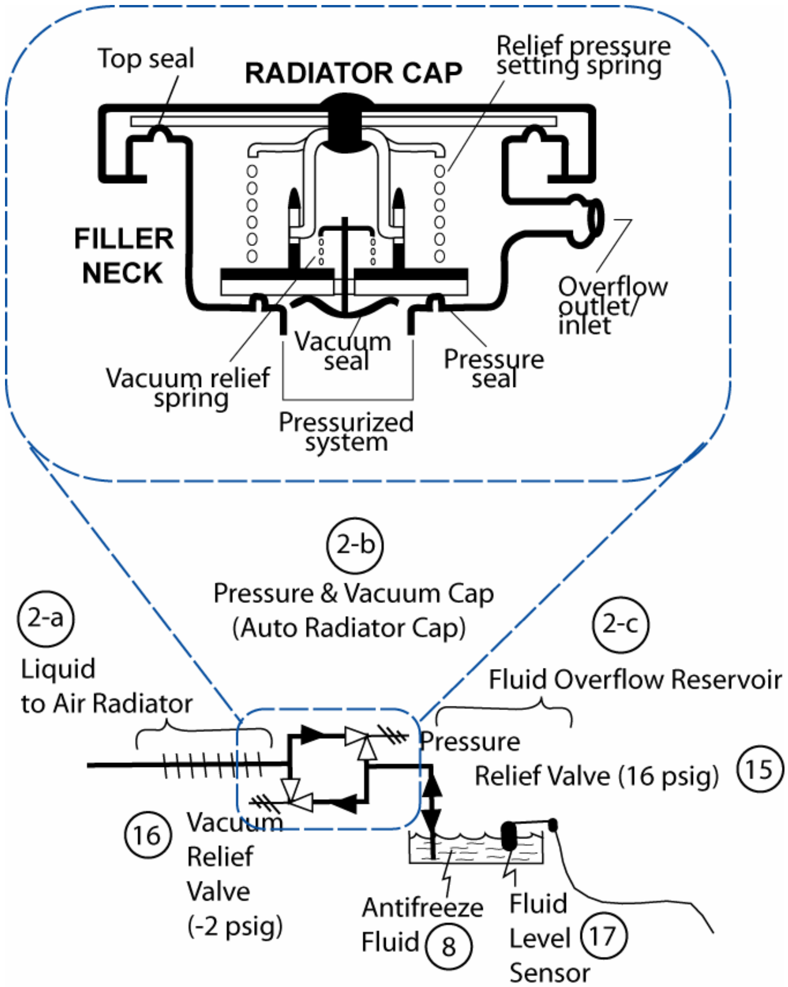


Figure 2.7 Parallel Pressure & Vacuum Relief Valves Inside the Radiator Cap

2.2.4 <u>Fluid Overflow Reservoir & Recovery System</u>

This reservoir is there to catch any fluid forced out of the heat transfer loop by thermal expansion or boiling in the loop. The reservoir is maintained at half full normally and the fluid from the heat transfer loop enters and exits from the fluid reservoir at the bottom below the waterline. Hence, once all air has been expelled from the fluid loop, the coolant recovery system keeps air from getting back in. Just like in your automobile's radiator, this lowers the corrosion rate in the fluid loop. **CAUTION: ONLY OPEN THE RADIATOR CAP WHEN THE SYSTEM IS COLD. IF YOU MUST OPEN THE RADIATOR CAP WHEN THE SYSTEM IS IN OPERATION, WEAR LEATHER GLOVES AND FACE SHILED TO AVOID SCALDING YOUR ARMS, HANDS AND FACE**

The overflow reservoir fluid level is measured by a float switch (17). When the fluid reservoir is low the switch turns on the red LED (check fluid level light) at the hot water

tank. Fluid can be pumped in from the fill/drain valve, or poured into the reservoir from the top.

2.3 Insulated Umbilical, including Fluid Tubes & Electric Lines

The umbilical is composed of the two 3/8-inch diameter copper circulation tubes (3-a) in Figure 2.0, which are surrounded by closed-cell foam insulation (3-b) that is about 1.27 cm (½ inch) thick. Electrical wires from the roof to the water tank are placed on the outside of the insulation (3-c). For protection from the elements and ultraviolet light the entire ensemble is placed inside 2-inch diameter ABS pipe when it is outside or on the roof.

2.3.1 Copper Circulation Tubing & Compression Connectors

The copper tubing used to connect the solar collector to the Wand is standard soft copper refrigeration tubing with 3/8 inch outside diameter. The specifications are shown in **Table 2.1**. The tubing is cleaned and annealed to "dead" soft for ease of running through crawl spaces and attics. The fluid supply and return lines are run right next to each other. Small plastic clips are used every 15.24 cm (6 inches) along the length to keep the tubes from touching each other. The copper tubing easily bends around a 0.15 m (6 in.) radius by hand. With a tubing bender, radiuses of 0.025 m (1 in.) can be made easily without kinking the tubing. Reasonable care must be used to route the tubing to avoid kinking and over-flexing which would cause the tubing to crack, then leak. The tubing heats up and cools off each day, so it needs to be loosely mounted to allow for expansion and contraction during heat up and cool down. These are the same considerations used by heating and refrigeration technicians to install the pressure and suction copper tubing from the outside compressor/condenser unit to the inside evaporator/air heat exchanger of a typical home air conditioning system.

All tubing connectors are standard 3/8" compression fittings. A standard tubing cutter and reamer are needed to cut the tubing and open up the end before installing in the connector. The compression fittings are tightened using two 6 to 8 inch adjustable wrenches. For installations requiring less than 25 feet of copper tubing no soldering of tubing joints is required to connect the heat transfer loop together since refrigeration tubing usually comes in 50-foot lengths. For copper tubing runs longer than 25 feet the tubing must be joined end to end. Since compression fittings can leak, joints in the 3/8-inch tubing that will be in inaccessible places like inside the umbilical insulation, should be soldered using sweated joints. These joints are common in refrigeration tubing connections and use a swaging tool to expand the end of one tube so the other tube end slides inside and can be soldered for a strong leak-tight connection. Sweat unions can also be used.

Table 2.1 3/8" Diameter Refrigeration Tubing Specifications

Outside Diameter	9.52 mm	0.375 in
Inside Diameter	7.9 mm	0.311 in
Wall Thickness	0.81 mm	0.032 in

2.3.2 Umbilical Insulation

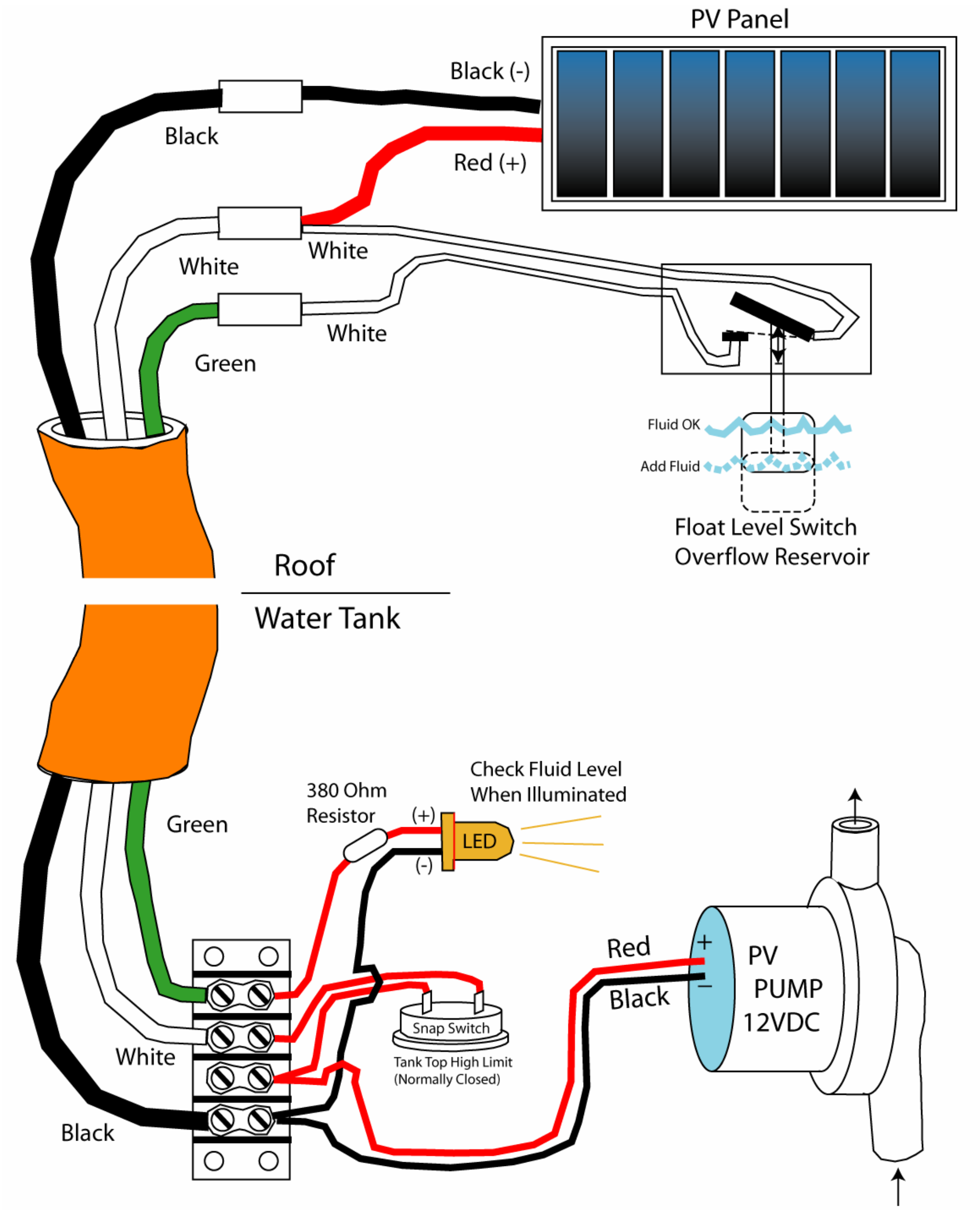
The trade term for the insulating rubber foam material is Rubitex™ or Armacell™. This type of insulation is resistant to moisture and is a closed-cell type, which does not allow moisture to penetrate or be absorbed. The rubber foam pipe insulation is split along its length with an adhesive to close the insulation around the pipe. Once the copper tubes are in place and next to each other the insulation is wrapped around them and the insulation bonded together along its length. Electrical tape is used to attach the electrical cable to the outside of the umbilical at 0.46 m (18 inch) intervals, to make a neat installation.

2.3.3 Umbilical Wiring

The cable, which comes from the roof to the hot water tank, serves two different functions. Carrying solar collector output temperature sensor data for the 115 VAC systems, DC power from the PV panel and float level signal for both systems. We recommend that two three wire extension cords be installed in parallel, when the system is first put in. This pair of cords gives three pairs of AWG #18 wires: two wires for a temperature sensor, two wires for the overflow float level indicator and two wires for PV power plus and minus. One cable three wire electrical schematics are provided, but we recommend as two cable set up since the cable is cheap and easy to run at this stage and very costly to install later.

For the 115AC system the temperature sensor on the solar collector must be connected to the pump control unit (6). This is a low voltage signal, usually 14VDC. For the 12VDC-powered system the power from the PV panel, usually 30 to 40 Watts, must be sent from the PV panel to the pump. This requires at least one pair of wires, which can handle the power without loss. Both PV and 115 VAC systems need two wires for the overflow float level indicator system. By using the two parallel extension cords, the system can be changed from 12VDC to 115VAC or visa versa without pulling any new wires, just connecting the end differently.

The PV powered system can use a single 3 wire AWG #18 extension cord as discussed in Figure **2.8**. The PV negative connects to the black wire. The PV positive and one float level switch wire connect to the white wire and then connect the other float level switch lead to the green wire. At the water tank the PV positive (white) is connected through the water tank high limit snap switch to the pump positive. The PV negative wire (black) is connected to the pump negative. The float level switch green wire is connected to an LED light positive and the LED negative goes through a resistor to the PV negative (black). Now the PV powered level light will be on when the fluid is low and the sun is out.



Butler Sun Solutions Wiring Diagram for PV Powered Pump with Snap Switch High Limit And Float Level Minder LED System

Figure 2.8 Typical Wiring Diagram for PV Powered System

2.3.4 Split Pipe

When the umbilical is routed outside where it can be exposed to the weather, it must be protected from the elements. This is accomplished by using Standard 5.08 cm (2 inch) diameter Black ABS drain pipe as a protective covering which prevents the sun’s ultraviolet rays from destroying the rubber foam insulation. The ABS pipe can be slipped

over straight sections before they are bent, or split and fit over the wire, insulation and tubing. The couplings are split by sawing and placed around the bends and glued or mechanically fastened in place. **NOTE: CARE MUST BE TAKEN TO BE SURE THAT WATER WILL NOT BE TRAPPED INSIDE THE ABS PIPE COVERING SINCE IT IS NOT WATERTIGHT. DRAIN HOLES MUST BE DRILLED AT ALL LOW SPOTS TO ALLOW THE WATER TO DRAIN.** The pipe protects the insulation and wire from Ultraviolet radiation, and shields it from rain and moisture. The pipe is a weather shield, not a waterproof seal.

2.4 Solar Collectors

The Solar Collector(s) used with this system must be rated and certified by the Solar Rating and Certification Corp. (SRCC) OG-100 for the complete system to be OG-300 Certified. Only systems designated in **Table 1** will be certified SRCC OG -300, when the identified SRCC OG-100 collector is installed. The SRCC web site, www.solar-rating.org, will also have an updated list of the SRCC OG-300 certified Butler Sun Solution Systems. The SRCC OG-300 Certification is required to receive Federal and/or State tax rebates or credits for installing a solar hot water system.

The solar collector is of a standard design and will be provided with the system kit or can be purchased separately. The collector must be sized to provide the correct amount of heat to the hot water tank. Too large a collector area will overheat the hot water tank, causing the circulation pump to be shut off by the tank high limit switch on the top of the hot water tank or the Delta-T controller, so collected solar energy will be dumped in the liquid-to-air radiator. Too small a collector won’t heat the tank enough. A common design rule is that the collector area in square feet should be approximately the tank capacity in gallons divided by 1 for Northern latitudes and 2 for Southern latitudes. Local elevation, climate and the orientation of the solar collector(s) away from due South or latitude elevation will also factor into the solar collector size needed.

The solar collector must be Solar Rating and Certification Corp. (SRCC) OG-100 rated and certified. It should be single glazed with tempered float glass or low-iron, high-transmission glass. Double layered extruded Polycarbonate with Ultraviolet (UV) solar damage inhibitors has passed OG-300 and has an expected life of at least 15 years. The solar collectors should have copper fluid channels capable of withstanding 100- psi pressure and cause the fluid to flow in serpentine or parallel paths for high system performance. Parallel flow paths will work but may be lower in efficiency since it is hard to balance flow rates in parallel fluid tubes at low flow rates. The collector frame should be corrosion resistant extruded or formed aluminum, with an Ethylene Propylene Di-amine synthetic rubber (EPDM) gasket to hold and seal the glazing. The frame should support the absorber plate while positioning the low out-gassing, fire-retardant foam insulation in place and holding the bottom sealing plate in place. The frame will also be easily attachable to the roof and flashed in, or capable of being supported at an angle above the roof pitch. The SRCC Certified solar collectors listed on the SRCC web site will be appropriately vented to the atmosphere to prevent internal condensation and thus minimize corrosion to the collector outside of the fluid loop.

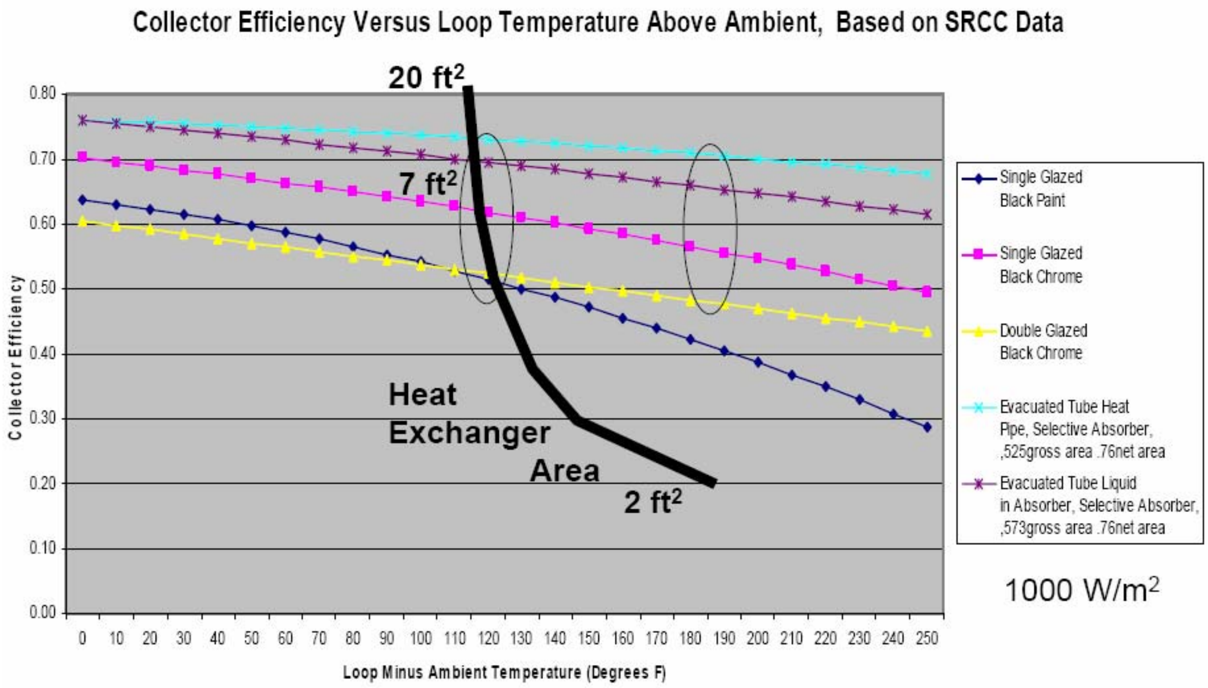


Figure 2.9 Heat Exchange Surface Areas vs. Loop Temperature & Collector Efficiency

The effects of heat exchanger surface area on closed loop temperatures for different types of solar collector are shown in **Figure 2.9**. The small, 2 square foot surface area of the "Solar Wand" drives the loop temperature of the system up compared to a Rheem-Rudd™ 20 square foot surface area heat exchanger, with the 7 square foot surface area Quad Rod™ in the middle. Increasing the loop temperature increases the solar collector heat losses. The "Solar Wand" works well with collectors whose heat losses do not increase dramatically with temperature. The solar collector has a much greater effect on system performance than the surface area of the heat exchanger for selective absorber surface solar collectors. For black painted solar collectors the higher loop temperatures dramatically decrease system performance. The "Solar Wand" should only be used with selective absorber surface solar collectors.

All SRCC OG-100 certified collectors meet the above criteria and also must have passed a cold-water shock test, where cold water is sprayed on a collector stagnated by solar heating without fluid flow. SRCC certified collectors must also pass a 30-day stagnation test without fluid loop degradation or other collector damage.

2.5 Circulation Pump

The circulation pump provided is of the seal-less, centrifugal type. The magnetic rotor is driven by chasing an electronically created rotating magnetic field, which is transmitted through a thin stainless steel wall. The electronics are on the outside of the wall and the pump rotor/impeller is on the inside with the heat transfer fluid so the electronic pumps

have no external bearings to lubricate or wear out. Information on seal-less pumps is provided in **Figures 2.10 and 2.11.** There is no rotating shaft seal in this type of pump to wear out. Motor driven seal-less pumps use an armature and bearings to create a rotating magnetic field with permanent magnets on the outside of the thin stainless steel wall. The DC solar pumps are designed for 150 psi pressure and 230°F operating temperature. The pump is supplied with a set of isolation valves so it can be serviced or replaced without draining the fluid from the solar system.

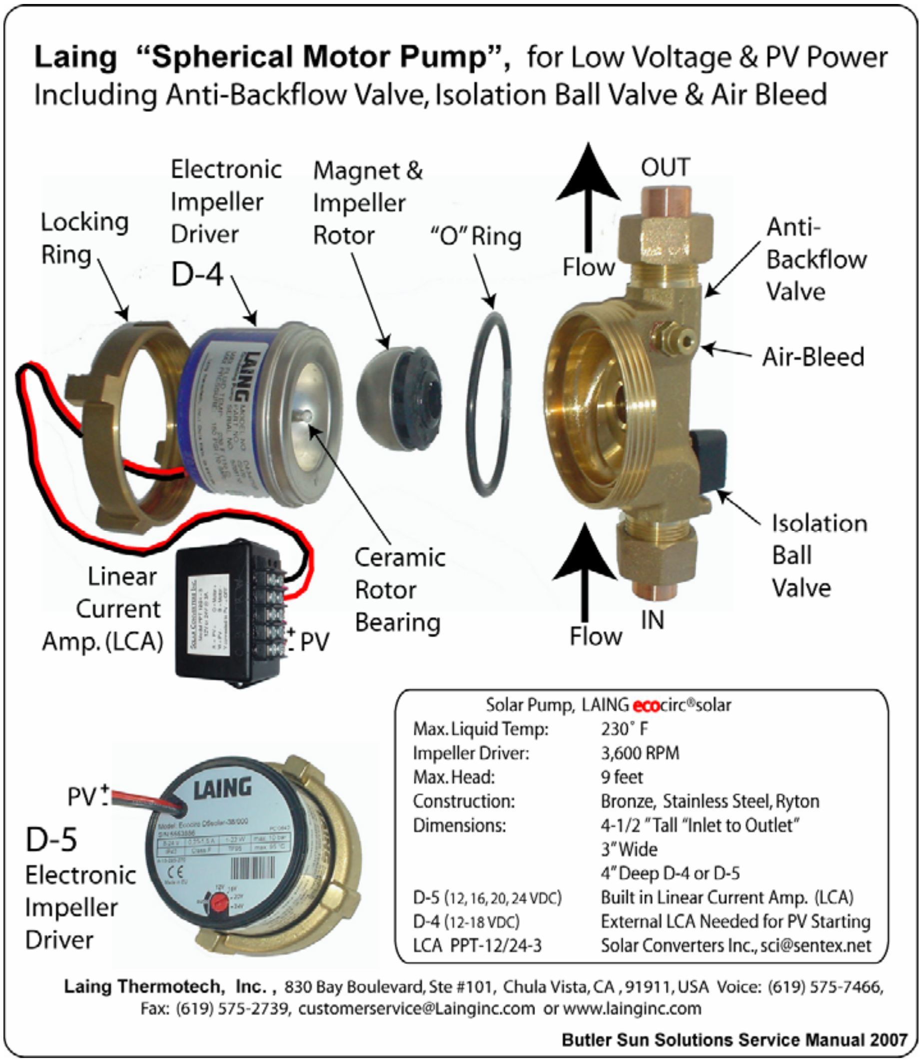


Figure 2.10 Laing Seal-Less Solar Circulation Pumps

Delta-T controllers that operate on 115VAC are sometimes preferred over PV panels to operate low voltage DC pumps. If a Delta-T controller is used to switch a 115VAC pump electrical outlet on and off, then a Class II 115VAC-to-(13 to 18) VDC transformer of 30Watt capacity is plugged into the outlet and used to power the DC pump.

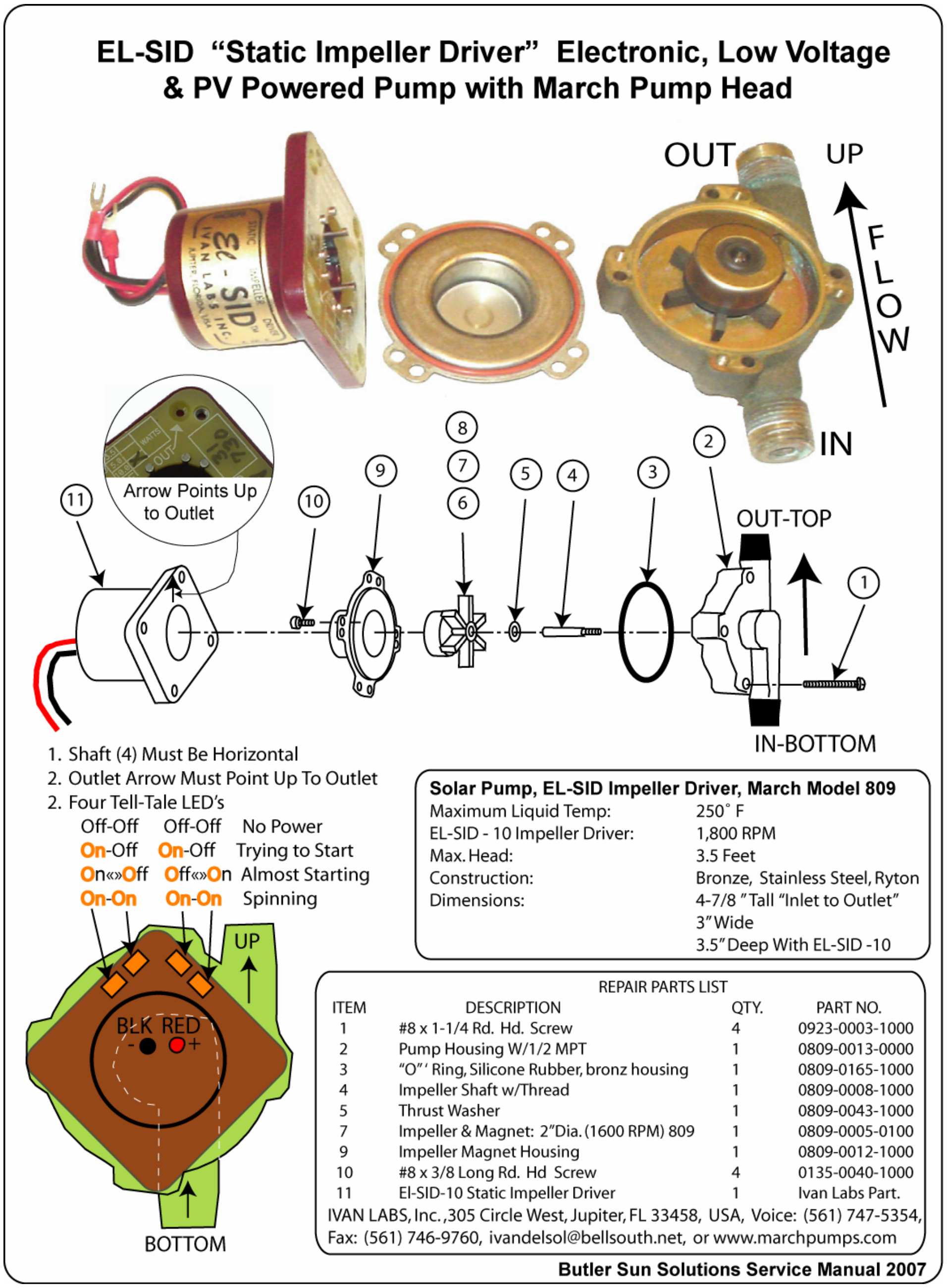


Figure 2.11 El-SID Solar Circulation Pump

Several low flow pumps powered by photovoltaic panels have been used successfully with the Solar Butler 1.0 system. **Table 2.2** shows a comparison of the pumps that have been successfully used in long life systems.

Table 2.2 Properties of DC Seal-less Pumps

Make	Model	Power Needed	RPM	Head Pressure
Laing	D-4 LCA external D-5 LCA	18VDC 15W	3450	10.5 Ft Head (4.60 psi)

	Internal			
Ivan Labs	El SID 2X2 El SID Max	18VDC 10W 18 VDC 20W	1720 1800	2.5 Ft Head (1.09 psi) 5.0 Ft Head (2.18 psi)

These pumps are compatible with all automobile antifreeze glycol-based solutions; however, we only recommend that propylene glycol be used in the system. **WARNING: ETHYLENE GLYCOL & ALCOHOL BASED ANTIFREEZE SOLUTIONS ARE NOT RECOMMENDED FOR USE IN THE SOLAR BUTLER 1.0 SYSTEM; THEIR USE WILL VOID YOUR WARRANTY.**

The construction materials of the pump and system are given in **Table 2.3**.

Table 2.3 Materials In Contact With Heat Exchange Fluid

Component	Copper & Compatible Alloys	Polymers & Ceramics	Ferrous Alloys
Tube Fittings	Brass		
Tubing	Copper		
Tubing Solder connection	Lead Free; Tin/Antimony		
Heat Exchanger Wand	Copper & Brass		
Solar Collector	Copper		
Solar Collector Silver Solder	15% Silver, Copper/Tin		
Radiator	Copper		
Pump Housing	Bronze		
Pump “O” Ring		EPDM	
Pump Impeller		Noryl (Polypropylene)	
Pump Bearing		Carbon Graphite/Ceramic	
Pump Container			316 Stainless Steel
Radiator Cap Seal		EPDM	
Radiator Cap Vent	Copper		
Radiator Cap Structure			Zinc Clad Steel
Filler Neck	Brass	ABS	
Overflow Tubing		EPDM	
Fluid Recovery Reservoir		ABS	

The pumps shown in **Figures 2.10 and 2.11** are electrically impedance-protected to prevent motor burn out. They are corrosion resistant and can be easily disassembled for

field repair. Years of testing have shown these pumps to be reliable and trouble free for over several decades in residential space heating applications with conditions similar to the ones found in the Solar Butler 1.0 system.

2.6 Controllers

2.6.1 Delta-Temperature Controls

The 115VAC system uses a standard Delta-T controller to sense the system temperatures and to turn the pump on and off. The controller uses the temperature inputs from the temperature sensors (6-a) at the solar collector outlet and sensor (6-b) at the hot water tank top to control the circulation pump. The pump only has two states: on and off. The controller state table is shown in **Table 2.4**.

Table 2.4 Solar Butler 1.0 Controller State Table for115 VAC System

SYSTEM STATE	SENSOR TEMPERATURES	PUMP STATE
ACTIVE SOLAR OPERATION	IF: The collector temperature is above tank top temperature by 16^{o}F (8.9^{o}C) AND: Tank top temperature is below maximum limit 185^{o}F (85^{o}C)	ON
OVER-TEMPERATURE	IF: Tank top temperature above maximum limit 185^{o}F (85^{o}C)	OFF
STANDBY	IF: Collector temperature less than tank top temperature	OFF

2.6.1.1 Temperature Sensors

The temperature sensors most commonly used are thermistor types. The thermistor sensor is a resistor whose resistance decreases with increasing temperature as shown in **Table 2.5**. The most common thermistor sensor is called a “10K Ohm”, which has about 10K Ohm resistance at room temperature of 75^{o} F. The resistance and temperature are highly non-linear; with temperature accuracy of plus or minus 5 to 10%. The fragile thermistor is potted into a short length of copper tube flattened on one end, with a 1/8” hole, to facilitate attachment to the system. These thermistor sensors have proven to be durable, rugged, accurate and reliable for long periods of time. Corrosion of the wires and connectors electrically connecting the thermistor to the controller has been far more troublesome. The controller does not know where the resistance is in the thermistor circuit, the controller sees the thermistor and all of its connector resistance. The thermistor mounted on the solar collector outlet line is most prone to thermistor or connector failure, since it is exposed to rain, thermal cycling, snow, dew and the wires to UV radiation. They should not need to be replaced over the life of the system, but checking the resistance from the controller will tell you if the sensor is giving the controller the correct reading. We recommend that all leads to and from the temperature sensing element be soldered to the leads to the controller. No wire nuts or crimped

connections should be used which can hold moisture and allow the electrical contract between the wires to corrode, adding resistance to the sensor electrical circuit which will be read by the controller as a decrease in the measured temperature. If the wire corrodes completely through and breaks the circuit, the controller thinks the solar collector is always below -50^{o}F and will keep the pump off. If the tank sensor wire corrodes through, then the controller thinks the hot water tank is below -50^{o}F and will keep the pump on all of the time, day and night.

Some of the newer controllers are using more accurate temperature sensors such as platinum resistance thermometers, wire wound resistance elements, semiconductors and thermocouples. These sensors are more expensive, but much more accurate, with accuracy of plus or minus 1-2%.

Table 2.5 Thermistor Temperature vs Resistance

Degrees Fahrenheit	Ohms
-50	491,400
-25	196,450
0	85,378
25	39,919
50	19,900
75	10,500
100	5,827
125	3,382
150	2,044
175	1,281
200	829
225	553
250	378

2.6.1.1.1 Solar Collector Outlet Sensor

The solar collector temperature sensor is placed at the top of the solar collector on the hot fluid outlet pipe.

2.6.1.1.2 Tank Top Temperature Sensor

TheCut Off Switch for top tank temperature must be slid under the insulation to touch the top of the metal tank. It must be in contact with the outside of the water tank itself, on or near the top of the tank. This is usually accomplished close to an outlet port where there is a gap in the sheet metal tank covering. **NOTE: THE TOP SENSOR MUST BE IN CONTACT WITH THE METAL SURFACE OF THE HOT WATER TANK TO ASSURE THAT THE CONTROLLER WILL SAFELY LIMIT TANK TEMPERATURE.**

The sensors are connected to the controller with two wires with a minimum wire gauge of #24. Sensor failures can cause the system to pump when the sun is not out, or not to pump when the sun is out. Refer to **Table 5.1** “Trouble shooting the System” to diagnose a bad sensor. If you suspect a bad sensor, check its resistance at room temperature. They

are calibrated to read 10,000 Ohms at room temperature 25^{o}C (77^{o}F) and have +/- 10% accuracy, see (**Table 2.5)**.

2.6.2 Insolation Powered Pump Control

The control for the 12VDC system is different; it consists only of a Photovoltaic panel on the roof and a PV-powered pump connected in series with a temperature limit switch on the hot water tank as shown in **Figure 2.11**. The high-temperature limit switch is placed at the same location as 6-b, but it is a thermally activated snap switch or thermally activated transistor switch which is adjustable and usually set so it opens at 185^{o}F (85^{o}C), and closes at about 165^{o}F (74^{o}C). The thermal switch is wired in series with the PV panel and circulation pump motor. Hence if the switch is open the circulation pump will not run. Simple linear CMOS semiconductor controllers are also being tested, which will use the power from the Photovoltaic panel to power a simple controller which uses a thermistor temperature sensor on the top of the tank to activate a transistor switch to turn the pump on and off.

Table 2.6 Solar Butler 1.0 PV System Controller State Table

SYSTEM STATE	SENSORS	PUMP STATE
ACTIVE SOLAR OPERATION	IF: The sun on the PV panel is intense enough to run the pump	ON
OVER-TEMPERATURE	IF: Tank top temperature above maximum limit 185^{o}F (71^{o}C)	OFF

2.7 Power sources 115VAC or 12VDC

There are two recommended power sources. The first is a standard power outlet (115VAC) with GFI (Ground Fault Interrupter) properly wired and tested. This should be a 3-wire grounded outlet. An outlet tester should be used to verify that the outlet is working properly. A Class II transformer can be used on the controller outlet to convert the 115VAC output into 18 VDC for powering low voltage pumps.

The second power source is a photovoltaic panel with a power rating of at least 20 Watts and not more than 32 Watts. The 20-Watt panel will begin pumping later in the morning and stop earlier in the evening than the 32-Watt panel. The pump will begin pumping after the sun is about 20 degrees above the East horizon; pump the heat transfer fluid all day, a little faster at noon, and stop pumping when the sun is about 20 degrees above the West horizon. This matches the solar input, and allows for the solar hot water system to work without being connected to an outside power source. The PV panel option is more popular, since it is simple and reliable and does not require any external power from the house. If there are trees or buildings which will shadow the PV array during normal sun hours, then 115VAC powered Delta-T control would be recommended.

2.8 Heat Transfer Fluid

The heat transfer fluid is a propylene glycol-water mixture, which is commonly used for automobile antifreeze coolant. A propylene glycol-water mixture will not poison pets or people and is non-flammable and non-toxic. Propylene glycol is an American Water Works Association (AWWA) Class II fluid. This means that it has a Gosselin toxicity rating below 1. Class II material are considered non-potable and may be objectionable, but not dangerous to the health of pets and people.

Table 2.7 Physical Properties Of 50% Propylene Glycol 50%Water Mixture By Volume

Service Temperature Range with 16 lb. Pressure Cap	Lower Limit or Freezing Point -32^{o}C (-26^{o}F), Upper Limit or Boiling Point, 124^{o}C (256^{o}F),
Additives	Dyes, Corrosion Inhibitors
Vapor Pressure	14.7 psia to 30.7 psia
Viscosity over temperature range of 27^{o}C (80^{o}F) to 60^{o}C (140^{o}F),	1.4 to 7.0 Centipoise
Specific Gravity	1.02
Heat Capacity	0.85 BTU/Lb. ^{o}F
Flash Point	Non-Flammable
Auto ignition temperature	None
System Volume	1 gallon to 2 gallons
Antifreeze Safety	Always keep antifreeze in a sealed, marked, proper container with a childproof lid.
Emergency First Aid	According to the Agency for Toxic Substances and Disease Registry (ATSDR) CAS# 57-55-6 Propylene Glycol Antifreeze and Deicing solutions, are not considered toxic by the FDA. Ingestion of small quantities from leaks or spills should not be cause for alarm for people or animals. Skin exposure should just be rinsed off with water. Ingestion of large quantities such as from storage containers, consult your doctor. Burns caused by hot fluid, see a physician
Proper Disposal	Depending on the local codes the propylene glycol should be disposed of in a dry well or a sanitary sewer, not a storm sewer. We recommend returning it to an auto parts store or chemical waste disposal site for recycling. To clean up spills, you can use paper towels or “kitty litter” to soak up the propylene glycol-water mixture and place it in the trash.

2.9 Pressure Gauge

The pressure gauge (9) in Figure 2.0 reads the fluid pressure in the heat transfer loop. When the system is off, it will read the pressure head of water in the heat transfer loop. One atmosphere (14.7 psi) will support a water column of about 32 feet. So the pressure gauge will read 4.5 psi for every 10 feet of elevation between the gauge and the radiator cap (2-b). The location of the pressure gauge in the system is shown in Figures 1.1 and 2.0. For a single story installation the gauge will read about 5 psi at night. When the system is operating in the daytime, the pressure will be the sum of the 5 psi head pressure and 16 psi pressure from the radiator cap (2-b), so the gauge will read 21 psi around noon, when the system is operating. Turning the pump on and off will change the gauge pressure by a small amount, usually 1 to 2 psi.

2.10 Temperature Gauge

The temperature gauge (10) in Figure 2.0 is either a bimetallic or paraffin filled automotive non-immersion type gauge, which reads the temperature of the tube bringing solar collector heated fluid to the wand heat exchanger. It is located near the top of the wand heat exchanger close to the top of the hot water tank, so it can be easily read. Normally the temperature gauge, when read between 10AM and 2PM on a sunny day, reads between 60^{o}C (140^{o}F) and 100^{o}C (212^{o}F). This means the system is working. Cooler temperatures may indicate a lack of circulation in the system.

2.11 Fill/Drain Valve

The fill and drain valve (11) in Figure 2.0 is used to fill the system from the bottom to get all of the air out or to drain the fluid out of the system. It is used together with the Flush Valve (12) in Figure 2.0 and Pump Isolation Valves (13) in Figure 2.0, they are used to pump or gravity feed the glycol-water heat transfer fluid into the system. This valve is used to drain the system to replace the heat transfer fluid every 5 years.

2.12 Flush and Fill the System Including Flush Valve

The Flush Valve (12) in Figure 2.0 and Fill/Drain valve (11) in Figure 2.0 are used to perform three functions. The first function is to flush the system with fresh water to clean out small particles, spider webs or other debris that may have found its way into the fluid loop during storage or installation of the system. The second function is to fill the system for the first time, by either gravity or pumping. The third function is routine replacing of the heat transfer fluid after 5 years of service. This can be done quickly and easily without going on the roof if an external fill pump is available. If no fill pump is available, then gravity can be used by filling fresh antifreeze from the roof as used antifreeze is drained out of the Flush (12) in Figure 2.0 and Fill/Drain (11) in Figure 2.0 valves. The Fill/Drain Valve (11) also serves as a place to attach a pressure gauge to verify that the heat transfer fluid is circulating properly.

2.12.1 Flushing the System

Flush the solar system wand, collectors, and tubing. Flushing is needed on initial filling of the solar system, to flush out any contamination, residue or debris (spider webs or dirt), which may have gotten into the system during storage, shipment or installation. **HINT: FLUSHING OUT THE COLLECTOR, TUBING FITTINGS AND VALVES AS INDIVIDUAL COMPONENTS BEFORE INSTALLATION WILL MAKE FLUSHING THE ENTIRE INSTALLED SYSTEM EASIER**. With the radiator cap in place, pressurized water (about 40 psi) from a **GARDEN HOSE TURNED FULL ON** or external pump is injected into the system using the Flush Valve (12) in Figure 2.0. With the Pump Isolation Valve (13) in Figure 2.0 closed, the fluid must go up through the tubing to the collector, through the collector, down through the tubing to the heat exchanger wand, then out of the Fill/Drain Valve (11) in Figure 2.0. Water flushing should continue until the return fluid is bubble-free and clear of debris.

2.12.2 Filling the solar system with antifreeze:

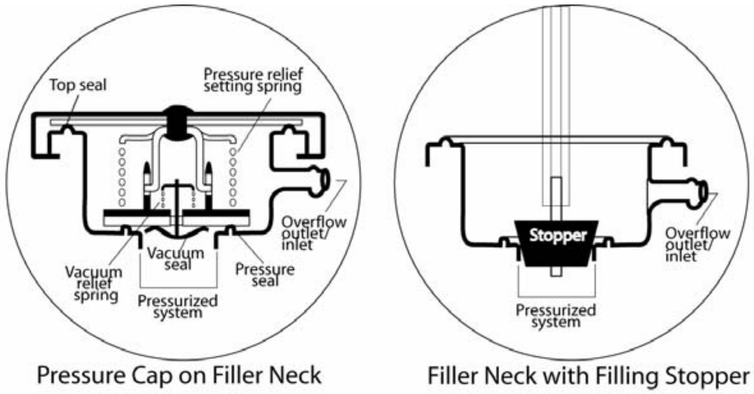
2.12.2.1 Filling the System Using Gravity

A single person can fill the system using gravity via the Stopper/Siphon method described here, but it cannot be done at low temperatures below 20°F (-7°C) where the water used for flushing the system might freeze (although one creative individual used hot water from the tank for flushing, then this method to fill, before the collectors could cool off too much). You will need to have access to the roof to get to the Self-Pressurizing Unit filler neck and reservoir, a container of antifreeze mix which is greater than the system volume (usually one to two gallons) and the rubber stopper with siphon tubing to replace the radiator cap. This arrangement is shown in **Figure 2.12**.

Mix up a gallon of 60/40 propylene glycol/water mixture by volume. The higher concentration is needed so water not flushed from the system will not dilute the mixture below 50/50. If your climate requires higher concentration, start with an even higher initial concentration mixture.

Remove the radiator cap and place the stopper in the filler neck as shown in **Figure 2.12**. Place the other end of the Stopper/Siphon tube into the bottom of a 1 to 2 gallon container of antifreeze. Now, as water is drained from the system, antifreeze mixture will replace it.

At the water tank, close the Pump Isolation Valve (13) in Figure 2.0 and open the Wand Isolation Valve (14) in Figure 2.0. Connect a ¼” plastic tube to the Flush Valve (12) in Figure 2.0 and put the other end into a clean pail or other container. OPEN the Flush Valve (12) to drain out fluid until it changes from clear water to the color of the antifreeze being added at the filler neck, and then CLOSE the Flush Valve (12). OPEN the Fill/Drain valve (11) in Figure 2.0 to drain out fluid until it changes from clear water to the color of the antifreeze being added at the filler neck, and then CLOSE the Fill/Drain Valve (11). Reopen the Pump Isolation Valve (13), Reattach the pressure gauge from the Fill/Drain Valve (11) and open the valve so the pressure gauge will show the pressure. Go back to roof, remove the stopper, fill the filler neck, fill the reservoir at least half full then replace and tighten the radiator cap.



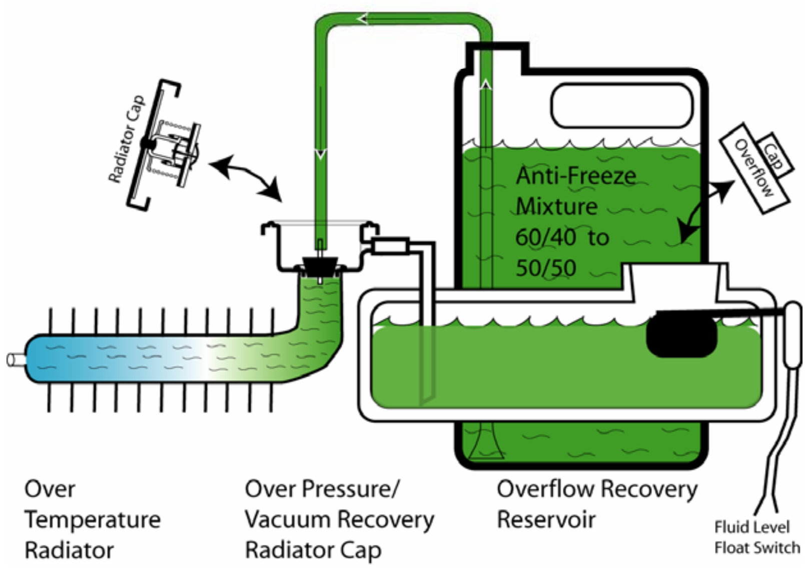


Figure 2.12 Siphoning Antifreeze into the System to Replace the Flush Water

2.12.2.2 Filling The System Using An External High Pressure Pump

Make sure that the overflow reservoir is empty of water and that the radiator cap is closed tight. At the water tank, close the Pump Isolation Valve (13) and open the Wand Isolation Valve (14). Connect a ¼" plastic tube from the high pressure pump outlet to the Flush Valve (12). Connect a ¼" plastic tube from the Fill/Drain Valve (11) to bucket to hold the water that will be pushed out of the system. Place the high pressure pump inlet tube in the bottom of the antifreeze fluid container. With the Flush Valve (12) and Fill/Drain Valves (11) open turn on the pump and the antifreeze will push the water out of the system. When the fluid in the tube from the Fill/Drain Valve (11) to the bucket turns green, meaning antifreeze has filled the system, then relocate the tube from the bucket and place it in the bottom of antifreeze fluid container so it will stay below the liquid level. Keep circulating the antifreeze until all bubbles are out of the system. Then CLOSE the Fill/Drain Valve (11), this will cause the antifreeze to fill the overflow reservoir. After about 1 minute the overflow reservoir level light should be off indicating it is full,

CLOSE the Flush Valve (12) and turn the pump off. Remove the pump and tubing, then reattach the pressure gauge to the Fill/Drain Valve (11).

2.12.3 Heat transfer fluid replacement every 5 years

The pH of the antifreeze mixture needs to be tested every 5 years. New propylene glycol mixtures of 50/50 with water will have a pH = 8.6 when new. This is basic and will not corrode the copper tubing and solar collectors. The automotive antifreeze recommended is Peak Sierra, which includes a mixture of corrosion inhibiting buffers. The pH should be measured using a proper pool or spa test strip, and a small amount of fluid from the system. If the pH changes to 7 or below, the antifreeze must be changed. The reason for this is that acidic antifreeze will corrode pin holes in the copper tubing and solar collectors. If the antifreeze needs replacing follow the procedures outlined in 2.12.2.1 for gravity change or 2.12.2.2 for external pump change. Draining or Pumping should continue until the new fluid container is near empty and the disposal container is near full. A typical system with 4 square meters (40 square feet) of solar collectors and balance of system contains about 4 Liters (1 gallon) of antifreeze. Recover the spent fluid into a suitable container for recycling or proper disposal.

2.12.4 Pressure Gauge Attachment to System

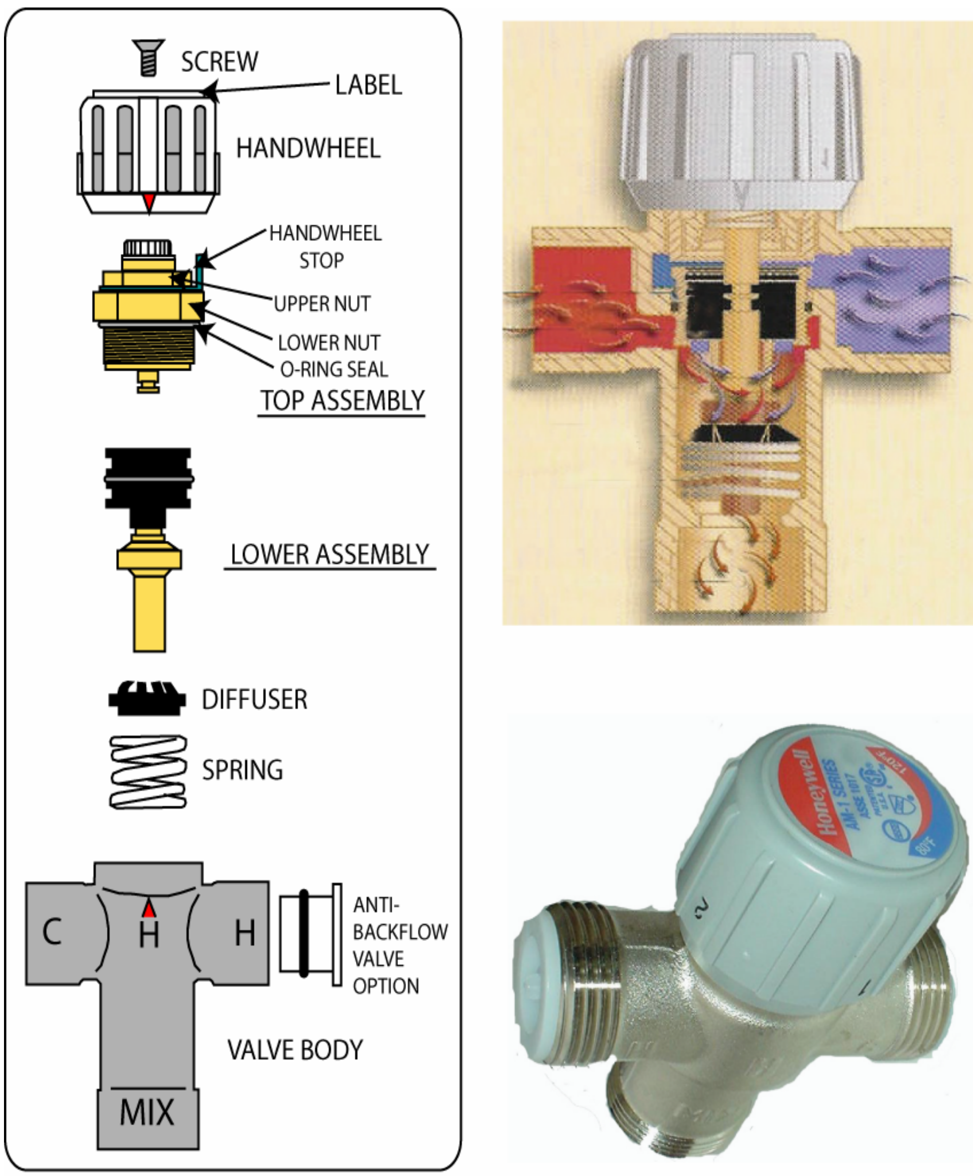
The Fill/Drain Valve (11) in Figure 2.0 is on the outlet side of the circulation pump. Once the pressure gauge is attached to it the valve can be opened and will allow the pump outlet pressure to be read on the pressure gauge (9). Turning the pump on and off will change the gauge pressure by a small amount, usually 1 to 2 psi. The easiest way to determine if circulation is occurring is to quickly close the Pump Isolation Valve (13), if fluid is circulating the pressure gauge will spike up by about 5 psi, then settle back to 1 to 2 psi. This “ping” test uses the momentum in the moving fluid to create the spike in pressure when the fluid flow is quickly blocked; hence it is the best test for fluid circulation. No pressure rise when the pump is turned on and no 5 psi “ping” test means that circulation is not taking place because there is an air bubble in the circulation pump, system blockage, or insufficient fluid in the system. Be sure that the Pump Isolation and Wand Isolation Valves (13, 14) are open, the Fill/Drain Valve (11) is open so the pressure gauge is reading and that the Flush Valve (12) is closed and the Radiator Cap (2-b) is in place and tight.

2.13 Circulation Pump Isolation Valves

The Pump Isolation and Wand Isolation Valves (13, 14) in Figure 2.0 are on the inlet and outlet sides of the circulation pump. Once they are closed, the pump can be removed from the system for service or replacement. The pump removal fluid loss will be refilled with fluid from the overflow reservoir over the next few days of operation. Check to be sure the reservoir is full and add fluid if necessary. Once the pump is reinstalled then the Pump and Wand Isolation Valves (13, 14) can be reopened and the system put back in service. The Pump Isolation Valve (13) is closed to flush and fill the system upon installation and to replace the heat transfer fluid every 5 years or as needed.

2.14 Anti-Scald Valve

The Anti-Scald valve (19) in Figure 2.0 blends cold water from the tank inlet with hot water from the outlet to achieve a uniform outlet temperature between a minimum of 27°C (80°F) and a maximum of 49°C (120°F) settable using the rotating handwheel. Thus the maximum water temperature delivered to the house is limited to 49°C (120°F). Many new homes already include Anti-Scald valves as they become more affordable and reliable. This is a safety upgrade, which increases the value of the solar system by making more effective use of the solar heated water and protecting the hot water users from scalding. The Anti-Scald valve must be installed to receive the benefits of SRCC OG-300 Certification. For disassembly and cleaning see **Figure 2.13**.



HONEYWELL AQUA MIX ANTI-SCALD VALVE (AM-101C): DISASSEMBLY FOR DESCALING SOAK HOUSING AND LOWER ASSEMBLY IN VINEGAR SOLUTION

Figure 2.13 Anti-Scald Mixing Valve

3.0 Water Tank Nomenclature

3.1 Hot Water outlet

This is the hot water outlet connection to the house hot water supply. This is where the heat exchanger Wand must be installed. Newer hot water tanks identify the hot water outlet with a red ring or the letter H embossed in the sheet metal near it and cold water inlet with a blue ring or the letter C embossed in the sheet metal near it. If these identifiers are missing, do the following to find out which one is hot. Turn on a hot water faucet in the house, and then carefully determine which one is hotter with a thermometer or other safe means. The hot water outlet will be hot! **CAUTION: DO NOT TOUCH THE HOT WATER OUTLET!** The cold water inlet will be cold. Mark them hot and cold with an indelible marker or other suitable label. **NOTE: HOT WATER OUTLET IS THE CONNECTION INTO WHICH THE WAND HEAT EXCHANGER FITS. DO NOT TRY TO INSTALL THE WAND IN THE COLD WATER INLET CONNECTION. IT WILL NOT FIT.**

NOTE: IT HAS COME TO OUR ATTENTION THAT SOME HOT WATER TANKS HAVE NECKED DOWN REGIONS BELOW THE THREADS ON THE HOT WATER OUTLETS. THIS REQUIRES THAT THE NECKED DOWN REGION BE FILED OFF BEFORE THE WAND CAN BE INSTALLED, SEE FIGURE 2.2.

NOTE: BRADFORD-WHITE TANKS HAVE A SACRIFICIAL ANODE UNDER THE HOT WATER OUTLET NIPPLE AND ATTACHED TO IT. INSTRUCTIONS FOR INSTALLING THE "SOLAR WAND" ARE IN FIGURE 2.3.

3.2 Cold Water Supply

This is where the cold water from the street or other house supply enters your hot water tank. It should have been identified and labeled as outlined in section 3.1 above. The cold water supply should have a shut off valve at or near the hot water tank. It there is no shut off valve (E) one must be installed to be OG-300 compliant, see **Figure 2.0**.

3.3 Cold Water Distribution Tube

This is a plastic or metal pipe, which directs the incoming cold water to the bottom of the hot water tank. Since hot water rises, the cold water must be sent to the bottom of the tank so the tank remains stratified. Stratification means that hot water because of its lower density rises to the top of the tank and cold water because of its higher density settles to the bottom of the tank. Hot water for home use is taken from the top of the tank.

3.4 Hot Water Tank Overpressure/Over-temperature Relief Valve

This is a special protection valve mandated by plumbing code to keep your hot water tank from exploding if it boils due to the heating element being stuck in the "on" position. **CAUTION: DO NOT TAMPER WITH THIS VALVE OR REMOVE IT FOR HEAT EXCHANGER WAND INSTALLATION.**

3.5 Cold Water Shut Off Valve

In most houses this is located at the service entrance to the house and shuts off water to the entire house. Some houses have a shut-off valve between the house service entrance and the hot water tank. Locate this valve and mark it. You will need to shut off water to the tank for a short time during installation of the Wand heat exchanger. SRCC OG-300 requires that a valve be installed in the cold water line, before the hot water tank, if no service entrance valve exists and water can only be shut off at the street tap.

3.6 Drain Valve

This is the valve used to drain your hot water tank when needed. Please see your water tank instructions for how often you should do this to lengthen tank life. You should use the drain valve to empty the water out of the tank prior to Wand installation.

CAUTION: ALWAYS ATTACH A HOSE TO THE DRAIN VALVE BEFORE OPENING. DO NOT OPEN THIS VALVE WHEN HOT PRESSURIZED WATER IS PRESENT. HOT WATER CAN SPRAY OUT AND SCALD YOU. TURN OFF THE POWER TO THE TANK AND LET THE TANK COOL. DEPRESSURIZE THE TANK BY SHUTTING OFF THE COLD WATER SUPPLY AND OPENING A HOT WATER FAUCET IN THE HOUSE BEFORE OPENING THE DRAIN VALVE.

3.7 Gas Burner or Electric Heating System

The gas or electric heating elements and systems are not disturbed by the heat exchanger wand installation. The wand should not contact them during installation and operation. Care must be used to be sure the Wand goes straight down and does not contact the electric elements or center pipe of gas hot water heaters.

The control set point of the gas or electric heater should be set at 120^{o}F (48.9^{o}C) after the solar Wand heat exchanger is installed. This allows for excellent solar hot water production, while allowing the hot water after several cloudy days to be warm enough for household use.

4.0 System Operation

4.1 Operation

The system begins operation in the morning when the solar collector temperature exceeds that in the hot water storage tank by about 16°F (8.9°C), or for PV powered systems when the insolation is above 300 Watts per square meter. Operation is defined as circulating the heat transfer fluid between the solar collector and the hot water tank. System shut down at night, circulation ceases, when the temperature in the solar collector is only 4°F (2.2°C) above the tank temperature or for PV powered systems when the insolation is below 300 Watts per square meter. The difference in start-up and shut-down temperatures is necessary to keep the system from cycling on and off rapidly at start-up. Clouds or overcast conditions can cause the system to shut-down and when the sun reappears the system will begin circulating again.

Operation is most easily described by following an element of heat transfer fluid through the system. The system is described in **Figures 1.1; 1.2; 1.3 & 2.0**. Use **Figure 2.0** on page 19 to understand the fluid flow by the numbers. The fluid starts at the pump (5). When the controller or PV power turns on the pump it means that the solar collector is hotter than the hot water tank by more than 16°F (8.9°C). The fluid passes by the Fill/Drain Valve (11) , which is open to the pressure gauge, and the fluid has its pressure read by Pressure Gauge (9), then the fluid passes through the open Pump Isolation Valve (13), then past the closed Flush Valve (12) . The fluid then moves inside the small diameter copper tubing toward the collector. This fluid will return to the pump in about one minute. The small diameter tubing enters the insulated Umbilical (3). The fluid travels in this insulated tunnel until it reaches the bottom inlet of the Solar Collector (4). The fluid then moves through the collector tubes exposing it to the sun's heat. The fluid typically warms up by 15°F (8.3°C) going through the collector. The protective transparent glass or plastic cover lets the light in and stops air convection from removing the heat. The insulation behind the collector tubing keeps the heat from going out of the back of the collector. The fluid exits the collector and passes a turn off into the Liquid-to-Air Radiator (2-a), the Pressure & Vacuum Cap (2-b), and Fluid Overflow Reservoir (2-c). The fluid has its temperature read for Delta-T controller systems by the collector outlet Temperature Sensor (6-a) on the outside of the tube and heads back into the insulated Umbilical (3). The fluid then travels in the umbilical to the hot water tank where it has its temperature read and displayed by Temperature Gauge (10), then the fluid passes through the Wand Isolation Valve (14) and then fluid enters the Heat Exchanger Wand (1). The fluid travels down the center of the wand to the bottom and then it turns around and returns in the annular space where it heats the first wall. The first wall heats the fluted fins of the second wall by contact conduction, which then heats the water inside the hot water tank. The fluid is cooled by about 15°F (8.3°C). Upon exiting the Heat Exchanger Wand (1) the fluid heads back to the circulation pump. Once safely back in the circulation pump the fluid is ready to go around again and again etc. The average fluid temperatures in the heat transfer loop are typically 180° to 200°F (82° to 93°C) near solar noon and lower earlier and later in the day.

4.2 Stagnation

Another mode of operation takes place when you do not use the hot water in your tank, such as when you go on vacation. The hot water tank is protected from getting too hot by the control system. The thermistor measuring the tank temperature tells the controller the tank does not need any more heat, and then the controller shuts off the circulation pump. This is a limit adjusted into the controller when the system is installed. For PV powered systems there is a thermal cut off switch on the hot water tank that will shut off the pump if the tank gets too hot. Refer to **Figure 2.4** which shows the Self-Pressurizing Units' operation. With circulation stopped the fluid in the collector gets hot enough to boil at 124^{o}C (256^{o}F) at 16 psig pressure. The built-in liquid-to-air radiator (2-a) between the solar collector and the Pressure Vacuum Cap (2-b) condenses the steam and keeps the collector from boiling over through the radiator cap. The steam absorbs heat in the collector and gives it up by condensing in the radiator, like a steam heat pipe. The radiator fins give up the heat to the surrounding air. This process forces some fluid and steam through the radiator cap into the overflow reservoir (2-c). The steam that makes it to the overflow reservoir is condensed in the fluid slightly diluting it. At night the steam in the closed loop condenses and draws fluid back in from the coolant overflow recovery reservoir (2-c) to refill the collector. This action is normal, does not cause any damage to the solar system, and will stop when circulation is resumed. So when you come home from vacation and start using hot water again, the solar heats your water automatically. When you go on extended vacations, you do not need to do anything with your solar collector. It is designed to take care of itself.

4.3 Controller and Hot Water Tank Settings

There are two user-adjustable settings on the solar system. The water tank top temperature limit can be set from 105^{o}F to 200^{o}F (40.6^{o}C to 99.3^{o}C). We recommend settings from 150^{o}F to 185^{o}F (65.6^{o}C to 85^{o}C). For PV powered systems the high limit cut off switch is a fixed or variable set point snap action switch, which opens at 150^{o}F to 190^{o}F (65.5^{o}C to 87.7^{o}C) and closes automatically 40^{o}F (22.2^{o}C) below the opening set point. **CAUTION: TANK TOP TEMPERATURES OF 150^{o}F to 185^{o}F (65.6^{o}C to 85^{o}C) CAN RESULT IN VERY HOT WATER, WHICH CAN SCALD, ALWAYS TEST THE WATER BEFORE YOU USE.** The pump turn-on differential temperature, Delta-T controllers, can be set from 8^{o}F to 24^{o}F (4^{o}C to 13^{o}C). We recommend setting it at 16^{o}F (8.8^{o}C). PV powered system turn on when the insolation is about 300 Watts per square meter and no adjustable settings are needed.

The hot water tank temperature setting for the electricity or gas is user controlled. The water tank temperature will fall to the gas or electric backup set point after several days of cloudy weather. This should be WARM, which should be near 120^{o}F (49^{o}C). If the temperature is set below WARM, the faucet and shower water may be too cool. If the back-up temperature is set too high, the solar heating of the water will be reduced, since solar will not heat above 185^{o}F (85^{o}C), the maximum high limit set point. The homeowner can and should adjust the back-up gas or electric set point temperature to be comfortable at the back up temperature, such as 120^{o}F (48.8^{o}C).

5.0 Maintenance Plan and Instructions

5.1 Checking the System for Operation

If the temperature gauge on a sunny day reads between 10AM and 2PM, reads between 54°C (130°F) and 100°C (212°F) then the system is working OK.

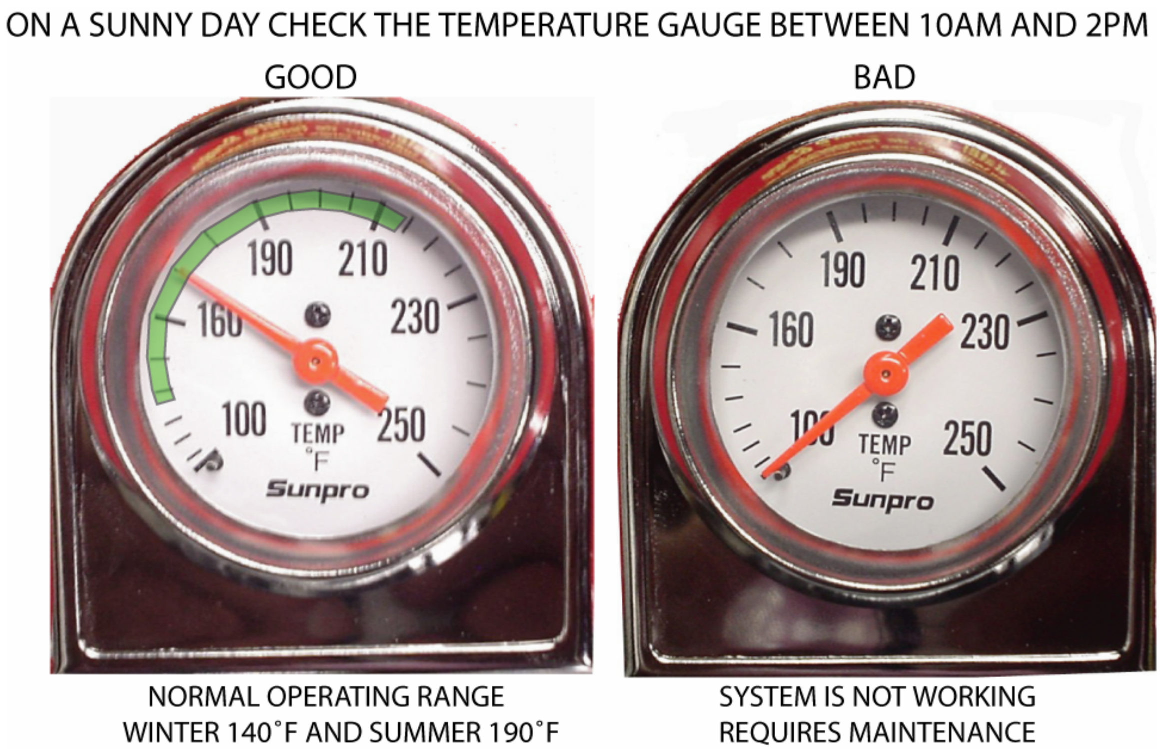


Figure 5.1 System Operation Analysis With Temperature Gauge

The system requires very little maintenance. The controller has operating lights which tell: the controller's status, when the line power is on, and that the pump is turned on. The third light on the lower right is for freeze circulation of non-freeze protected systems, which is not used on this system. Every six months look at the controller during a sunny day to see if the pump light is on. Two lights will be on: the "power on" and "pump on" lights. When the "pump on" light is on for Delta-T controllers, read the temperature gauge (10) in **Figure 2.0** mounted near the pump. For PV powered El-Sid pump shown in **Figure 2.10** on page 33, check the 4 LED's on the pump's body, which should all be flashing, to show the pump is running. For the Laing pumps shown in **Figure 2.9** on page 33, touch the plastic body to feel the vibration which tells that the pump is running. If it is not hot enough the homeowner should check to see if the low fluid level light is illuminated for the coolant overflow recovery reservoir. Add the proper propylene glycol-water mixture to bring the level in the overflow tank up to half full. If the temperature returns to reading within the limits within a few days, all is well.

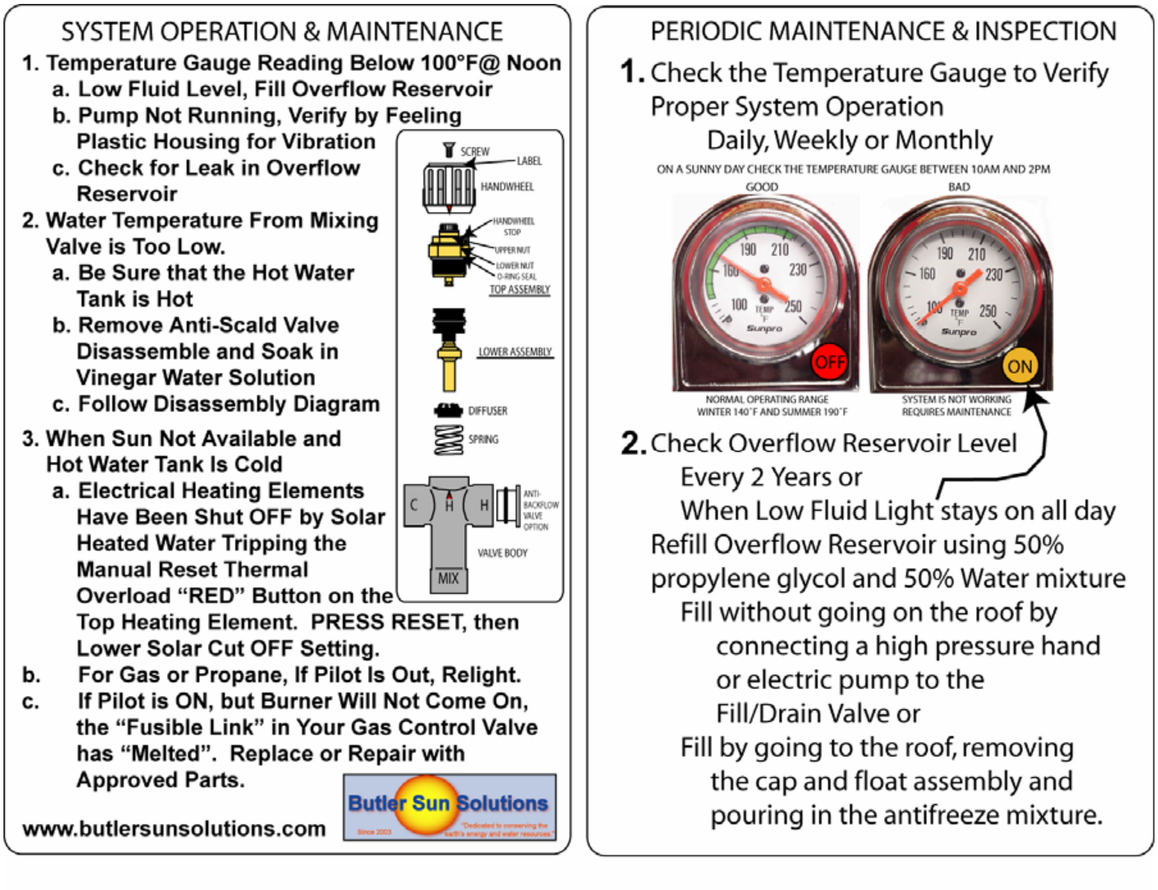


Figure 5.2 Maintenance Card to be Placed On Customer's Water Tank

Figure 5.3 Collar Sign on "Solar Wand" To Alert Plumbers

If the system temperatures do not return to normal then telephone or e-mail Butler Sun Solutions or your dealer/installer after trouble-shooting the system using **Table 5.1**.

Table 5.1 Troubleshooting the System

SYMPTOM	COMPONENT CHECK	POSSIBLE CAUSE	ACTIONS
Delta-T Controllers, Sun is Out & Pump is off	Controller Power light does not come on	Electrical outlet is not live.	Check outlet to be sure it has power, Fix or plug into a live outlet.
	Controller is not turning pump red LED on and energizing Pump. Plug a lamp into controller outlet and be sure it does not light.	Check to be sure that the Thermistors are placed in the proper locations of the collector and hot water tank.	Place Thermistors in the correct locations.
		Check to be sure that the Thermistors are connected to the proper terminals on the control board.	Attach to correct terminals.
		Check the Thermistors for Resistance Versus Temperature (Room Temp resistance 10,000 Ohms)	Replace bad thermistors
		Check for Thermistors connections to be sure they are tight.	Tighten connections
		Controller is bad.	Replace bad controller
	Pump not on, Controller red LED is on and Controller outlet is Live	Pump is not operational	Repair or replace pump
PV Powered Sun is out, Pump is OFF	PV panel to pump connection	Bad electrical connections or Polarity Reversed	Solder All Connections, Verify Polarity with a DC Voltmeter.
	Pump electronics driver	Check pump LED'S and for vibration.	Replace pump electronics
	Pump Impeller	Check impeller is free and not rubbing against the walls or debris.	Clean impeller of debris. If rubbing the walls, the bearing is bad, replace the impeller
Sun is out, Pump is ON, Temperature Gauge (10) reads below 60°C (140°F)	Pump not moving Fluid, Pressure gauge does not go up by 2 psig when pump is turned on.	Air trapped in the Pump	Put a blanket or cover over the solar collector. After collector cools off drain one pint of fluid out using drain valve, and fill from radiator cap. Check for circulation using the

			Pressure Gauge. Plug and unplug pump several times to move air bubbles out.
	Pump not moving Fluid, Pressure gauge does not go up by 2 psig when pump is turned on.	Air has been sucked into the system from the overflow reservoir.	Check for fluid level in the overflow reservoir. If it is very low check for leaks and repair them before filling.
Delta-T Controllers Sun is not out, Pump is ON,	Controller is not turning pump red LED off and de-energizing Pump. Plug a lamp into controller outlet and be sure it lights.	Check to be sure that the Thermistors are placed in the proper locations of the collector and hot water tank.	Place thermistors in the correct locations.
		Check to be sure that the Thermistors are connected to the proper terminals on the control board.	Attach to correct terminals.
		Check the Thermistors for Resistance Versus Temperature (Room Temp resistance 10,000 Ohms)	Replace bad thermistors
		Check for Thermistors connections to be sure they are tight.	Tighten connections
		Controller is bad.	Replace bad controller

5.2 Checking the System for Leaks

Check connections for fluid leakage or seeping. This is easily spotted as a green fluid, or a dried green buildup near joints. There are only four joints at the water tank and two at the collector. If there are joints in the tubing between the collector and the hot water tank, the contractor will identify them and you may have to remove insulation to see them. Joints in the umbilical should be coupled using a sweated solder joint. This could be accomplished by using a tubing expander to make the slip in fit, like refrigeration systems use, or could be a coupling, where both ends slide in and are sweated at one time. If any leakage is detected tighten the compression fittings and check the fluid level refilling if necessary.

CAUTION: NEVER OPEN THE RADIATOR CAP WITH THE SYSTEM HOT, OR WHEN THE SUN IS OUT. SCALDING STEAM CAN ESCAPE AND BURN YOUR SKIN.

HINT: PUT A BLANKET OVER THE COLLECTOR AND LET IT COOL OFF BEFORE OPENING THE RADIATOR CAP TO ADD FLUID DIRECTLY INTO THE SYSTEM.

5.3 Replacing the Heat Transfer Fluid

We recommend a fluid change once every 5 years over the life of the system. There are two ways to do this. The first uses an external fluid pump, the second uses gravity. Following these steps will make it go smoothly. All of the numbers are referenced to **Figure 2.0** page 17.

5.3.1 Changing the Fluid With an External Pump

1. Disconnect Power to the Circulation Pump (5) in **Figure 2.0**.
2. Connect the (manual or electric) system filling pump output to the Flush Valve (12) with ¼ inch diameter plastic tubing. Connect the pump inlet to a length of ¼ inch diameter plastic tubing and place the other end at the bottom of the container with the propylene glycol-water 50/50 antifreeze solution.
3. Remove the Pressure Gauge (9) and connect a length of ¼ inch diameter plastic tubing to the Fill/Drain Valve (11) and place the other end in a suitable container to catch the drained antifreeze solution.
4. CLOSE the Pump Isolation Valves (13). This will now force fluid to go to the collector to return to the Fill/Drain Valve (11).
5. Pump fresh fluid into the system until you see it coming out the Fill/Drain Valve (11) then pump a little more and stop.
6. CLOSE the fill/drain valve and pump for 30 seconds to fill the overflow reservoir.
7. CLOSE both the Flush Valve (12) and the Fill/Drain Valve (11).
8. Remove the tubing from the Flush Valve and Fill/Drain Valves.
9. Install the Pressure Gauge (9) on the Fill/Drain Valve (11) and REOPEN the Fill/Drain Valve, so the pressure gauge will read the system pressure.. NOTE: THE Pressure gauge will rise 1-2 psi when the system is circulating properly.
10. OPEN the Pump Isolation Valve (13).
11. Now the system is refilled with fresh Antifreeze and ready to run.
12. Plug the pump into a live outlet or reconnect to the PV panel and verify that a circulation has been established by reading the pressure gauge. NOTE: The Pressure gauge will rise 1-2 psi when the system is circulating properly. Do the "ping" test by quickly closing the Pump isolation valve (13) and watching the pressure spike up by about 5 psi the settle down to 1 to 2 psi.
13. Properly dispose of the drained antifreeze propylene glycol-water mixture.

    Depending on the local codes the propylene glycol should be disposed of in a dry well or a sanitary sewer, not a storm sewer. We recommend returning it to an auto parts store or chemical waste disposal site for recycling. As an alternative

clean up you can use paper towels or "kitty litter" to soak up the Propylene glycol-water and put it into the trash.

5.3.2 <u>Changing the Fluid Without a Pump, using Gravity Only</u>

1. Disconnect Power to the Circulation Pump (5) and cover the solar collectors with a blanket..
2. Arrange to have access to the Self-Pressurization Unit on the roof. Use the stopper and siphon configuration shown in **Figure 2.10.** HINT: If you don't have the stopper assembly, remove the 16 pound cap and have a Second person pour in the antifreeze mixture to keep the system full as you drain fluid from the bottom.
3. Back at the water tank, Attach a length of ¼ inch diameter tube to the Fill/Drain Valve (11) after removing the Pressure Gauge (9) and place the other end in the bottom of a container that will hold the drained fluid.
4. Close the Pump Isolation Valve (13)
5. OPEN the Fill/Drain Valve (11) and slowly drain fluid from the system. If you have the stopper siphon assembly or a second person on the roof, they will keep the system full as you drain out the old fluid.
6. Once you have drained out the darker old fluid and new fluid appears shut the Fill/Drain Valve (11).
7. Attach a length of ¼ inch diameter tube to the Flush Valve (12) then OPEN and slowly drain fluid from the system. If you have the stopper siphon assemble or a second person on the roof, they will keep the system full as you drain out the old fluid.
8. Once you have drained out the darker old fluid and new fluid appears shut the Flush Valve (12).
9. OPEN the Pump Isolation Valve (13)
10. Go back to the roof, replace the original 16-pound cap, fill the Reservoir and you are done.
11. Properly dispose of the drained propylene glycol-water mixture.

    Depending on the local codes the propylene glycol should be disposed of in a dry well or a sanitary sewer, not a storm sewer. We recommend returning it to an auto parts store or chemical waste disposal site for recycling. As an alternative clean up you can use paper towels or "kitty litter" to soak up the Propylene glycol-water and put it into the trash.

5.4 Fluid Quality, Toxicity, Safe Disposal

We recommend a fluid change once every 5 years over the life of the system. Under normal working conditions the system has a life expectancy of 35+ years.

CAUTION: PEAK SIERRA, THE RECOMMENDED ANTIFREEZE, COMES WITH INHIBITORS BUILT IN WHICH ARE PET SAFE AND NON TOXIC. DO

NOT BUY ADDITIVES OR COOLING SYSTEM CORROSION INHIBITOR FLUIDS SOLD AT AUTO STORES AND PUT THEM IN YOUR SYSTEM. IT VOIDS YOUR WARRANTY AND CAN MAKE THE HEAT EXCHANGE FLUID TOXIC.

The heat transfer fluid is a propylene glycol-water mixture, which is commonly used for automobile antifreeze coolant. Propylene glycol-water will not poison pets or people. Propylene glycol-water is non-flammable and non-toxic. Propylene glycol is an American Water Works Association (AWWA) Class II fluid. This means that it has a Gosselin toxicity rating below 1. Class II materials are considered non-potable and may be objectionable, but not dangerous to human health.

The system contains only a small amount of fluid, usually less than one gallon. A spill or leakage of the entire fluid inventory should not be a problem. You can mop it up and then dispose of it properly. Depending on the local codes propylene glycol should be disposed of in a dry well or a sanitary sewer, not a storm sewer. We recommend returning it to an auto parts store or chemical waste disposal site for recycling. As an alternative clean up you can use paper towels or “kitty litter” to soak up the propylene glycol-water and put it into the trash.

6.0 Specific Warning Labels

The labels are shown in **Table 6.0**. These labels should be filled out and attached to the system at appropriate locations.

Table 6.0 Specific Warning Labels for Solar Butler 1.0 System

1	Near Control Box and Hot Water Tank	Manufacturer: Butler Sun Solutions Address: P.O. Box 1666, Solana Beach, CA 92075-1520 Phone: 858-259-8895 E-mail: butlersunsolutions@roadrunner.com Website: www.butlersunsolutions.com System Type: Solar Butler 1 Date Manufactured: Month / Year System Serial Number: # _______________ For parts contact manufacturer For service contact the Installer
2	Near Control Box and Hot Water Tank	Installer : Name: Address: Phone: E-mail: Website:
3	On Pump	WARNING:HOT
4	Near Control Box and Hot Water Tank	Operating Parameters: Differential Temperature 16^{o}F (8.9^{o}C) Maximum Tank Top Temperature 185^{o}F (71^{o}C) Maximum Solar System Pressure 16 psig Freeze Protection -26^{o}F (-32^{o}C)
5	Fill /Drain Valve	Fill/Drain Valve Freeze Tolerance Propylene glycol-water 50/50 -32^{o}C (-26^{o}F) Propylene glycol-water 60/40 -48^{o}C (-54^{o}F) Heat Exchanger type DWP, AWWA Fluid Class II, Low Toxicity, See manual for proper handling & disposal instructions. Warning: Fluid may be discharged at high temperature, 127^{o}C (256^{o}F) and pressure, 16 psig. Warning: No other fluid shall be used that would change the original classification of this system. Unauthorized alterations to this system could result in a hazardous health condition.
6	Pump Isolation Valves	Pump Isolation Valves Valves -- Normally Open
7	Shower and Sink Outlets	Solar Heated Water Can Scald You!! Test The Water Before Anyone Bathes or Drinks.

7.0 Hazards of All Types

As a do-it-yourselfer, you must be comfortable assuming and mitigating the risks identified below. If you feel unqualified to assume these risks, we recommend that you hire a licensed contractor who is experienced with roof mounted solar installations.

7.1 Drinking Water Contamination Hazard

The system is designed to prevent cross contamination of the heat exchanger fluid with potable water. If water or heat exchanger fluid begins leaking from the top of the heat exchanger wand that means corrosion has breached a heat exchanger wall. Even though one wall is still intact, the heat exchanger should be removed immediately and replaced with a new one as soon as possible.

7.2 Hot Water Scalding Hazard

Hot water can scald you. Hot water can also be under pressure and squirt out. Wear leather gloves to protect your hands and Safety glasses or a face shield to protect your face when opening the Hot Water Tank Drain Valve and removing tank inlet or outlet fittings.

CAUTION: ALWAYS TURN OFF THE POWER AND OR GAS TO THE HOT WATER TANK, ALLOW THE WATER TO COOL OFF, AND RELIEVE PRESSURE TO THE TANK BEFORE LOOSENING ANY PIPE CONNECTIONS.

ALWAYS ATTACH A HOSE TO THE DRAIN VALVE BEFORE OPENING.

7.3 Ladder Hazard

Working on ladders is dangerous. Be sure that the ladder is properly placed and seated on the ground. Do not lean back while moving collectors from the ground to roof. Do not over-reach when running the fluid lines and umbilical. It is safest to have someone hold the ladder.

7.4 Falling Hazard

Working on roofs is extremely dangerous, and sure footing is required. Be sure to wear rubber-soled shoes, which cover your entire foot and are laced snugly. (Do not wear sandals or flip flops on roofs.) Falling to the ground can be deadly. Be sure to stay a safe distance from the roof edge. Do not use collectors as a support, even if they are attached to the roof. The collectors were not designed to be handrails. Plan the installation to place the collector on the roof safely and away from the roof edges.

7.5 Electric Shock and Fire Hazards

Do not drill into the roof or walls, until you have looked or verified using a stud, wire & pipe finder that no pipes or electric lines are in your drill path. If you have any doubts about what is inside the wall or roof, drill a small pilot hole and look or probe to be sure that it is safe to drill. Drilling into electric lines, water pipes or gas pipes can be both dangerous and costly to repair.

7.6 Electrocution Hazard

Beware of electric shock hazards. Do not stand in water and touch electrical components. Test the 3-pronged polarized, electrical outlet you intend to plug the controller into. Using an electrical outlet polarity and fault detector, check to be sure that the hot, neutral and ground are properly wired. A ground fault circuit interrupter outlet is recommended to reduce the possibility of electrical shock. Plug-in ground fault interrupters, which protect the controller, do not require an electrician and provide electric shock protection.

8.0 Service and Replacement Parts

As you can see from the parts list below, most of the spare parts are available from local supply stores and are stocked on their shelves for immediate delivery. The manufacturer or their outlets must provide only a few parts. These would need to be ordered and shipped, which takes time. These systems are easy for Do-It-Yourselfers or contractors to maintain and fix. The systems are designed to need very little service, but if they do the parts are readily available. **Table 8.1** is the System Parts List located on the next page.

The Manufacturer/dealer/distributor-supplied Replacement Parts are as follows:

- Solar Wand
- Solar Pump
- Solar Liquid-to-air radiator with filler neck attached
- Solar Collector
- PV Panel
- Solar Delta-T controller
- Solar Delta-T controller sensors

Hardware Store Supplied Replacement parts: (e.g. Home Depot, Lowes, Ace, etc.)

- Flexible hot water outlet line from hot water tank to house
- 3/8 inch copper tubing
- Rubitex R or Armaflex R pipe insulation
- 3/8 inch compression fittings
- Black ABS drain pipe
- Teflon Tape
- Control Wire
- Collector glazing
- Collector insulation
- Solder and copper splices for collector tubing

Auto Parts Store Supplied Replacement Parts: (e.g. NAPA, Kragen, Checker, etc.)

- Radiator Cap 16 lb., Non-Vented Type only.
- Propylene glycol Antifreeze (e.g., “Peak” or “Sierra” brands)

Table 8.1 Parts List for Collector Kit & User Supplied Parts

Parts List for Collector Kit				
LABEL	DESCRIPTION	PART #	REPLACEMENT SOURCE	
1	In-Tank Heat Exchanger Wand	1,010.00	BSS*	
2-a,b &c	Self-Pressuring Unit; Liquid-to-Air Radiator, including filler neck and Fluid Overflow Recovery System	1,002.20	BSS*	
2-b	Pressure/Vacuum Radiator Cap 16# non-vented	1,004.00	BBS*	Auto Parts Store

3-a,b,c	Insulated Flexible Umbilical Rubitex R Insulation Signal Wire Copper Tubing	1,007.00	BSS*	*** Hardware Store Hardware Store Hardware Store
3-a	3/8-inch Copper Tubing 50 Foot Coils	1,008.00	BSS*	Hardware Store
3-d	2” ABS Split Pipe and Elbows	1,005.00	BSS*	Hardware Store
4	Solar Collector, OG-100 Certified	1,001.20	BSS*	
5	Pump, low flow, seal-less	1,009.00	BSS*	
6	Delta-T Controller	1,003.00	BSS*	
6-a,b	Thermistor Sensors	1,011.00	BSS*	
8	Propylene glycol Antifreeze Mixed Equal Parts with Water	1,006.00	BSS*	Auto Parts Store
	PV Panel	1,012.00	BSS*	
*=Butler Sun Solutions				
User Supplied Parts				
	New Flexible Hot Water Outlet Pipe			Hardware Store
	Teflon Tape for Threaded Joints			Hardware Store
	Black Electrical Tape			Hardware Store
	Wire nuts or electrical Solder			Hardware Store
	Plumbers "Lead Free" Solder			Hardware Store
	Caulking in Tube with gun			Hardware Store
	Roof Sealing Compound (Tar)			Hardware Store
	Roof Patching Mesh			Hardware Store
	Metal Flashings if needed			Hardware Store
	Assorted Nails			Hardware Store
	Assorted Screws and Lag Screws			Hardware Store
	Collector Supporting and Elevating Hardware if Needed		BSS*	Manufacturers or Hardware Store
	2 inch ABS Drain Pipe, Elbows and Angles as needed			Hardware Store
	Zip Ties for Umbilical			Hardware Store
	1/8” Drill Bit for ABS Drain Holes			Hardware Store

9.0 Warranty Coverage

9.1 SCOPE OF COVERAGE

FIVE (5) YEAR WARRANTY ON PARTS AND MATERIALS

Butler Sun Solutions warrants all parts, materials and components installed according to the installation manual to be free of defects in materials or workmanship. This warranty shall be in effect for a period not to exceed 5 years from the date of system installation. This warranty shall cover the cost of parts or materials for repair or replacement of defective parts, materials or components.

TEN (10) YEAR WARRANTY ON THE SOLAR COLLECTOR

If Butler Sun Solutions provides the solar collector and balance of system we will provide the solar collectors manufacturers warranty against leakage due to corrosion.

WARRANTY ON REPAIR LABOR

If Butler Sun Solutions provides and installs the complete solar system, we will provide the one (1) year repair labor warranty.

If Butler Sun Solutions provides and someone else installs the complete solar system, Butler Sun Solutions recommends that the installer provide a one (1) year repair labor warranty. The end user must receive this warranty from the installer. Butler Sun Solutions will not provide this labor warranty to the end user for systems that Butler Sun Solutions does not install.

9.2 WHAT BUTLER SUN SOLUTIONS WILL DO

If a defect in parts, materials and components or other malfunction or failure to perform becomes evident during the warranty period. Butler Sun Solutions will repair or at its option replace the nonconforming component or part within a reasonable time, and without charge for the part or transportation. In such event, the duration of the warranty is extended while the part or component is not functioning.

9.3 WARRANTY PERFORMANCE (Where and How to File Claims)

Warranty claims are to be made to Butler Sun Solutions, during normal business hours, by the registered owner of the solar system. Registration must be done at the point of sale. Your contract for Butler Sun Solutions installed systems or invoice for systems purchased from Butler Sun Solutions automatically registers the owner. If you purchased

a system from a distributor or installer you will have to register on line or by e-mail. To verify that your warranty is still in effect, you must furnish evidence of the date of installation completion. Butler Sun Solutions may, if it deems it necessary and reasonable, arrange for a field inspection of the system, or request digital photos of the suspect component, within a reasonable time from receipt of a claim. The field inspector or photo evidence will be used to verify failure, establish the probable cause and determine corrective actions required. If the inspection/photos reveal a warranty-related defect, Butler Sun Solutions will replace or repair at its option the parts and components which have failed. If no warranty-related defects are found, the system owner must pay for the inspection. Butler Sun Solutions, or its representatives, shall be granted access to the solar system, and if necessary, a sample of or the complete failed part of the solar system may be shipped to us or taken for analysis.

9.4 LIMITATION OF LENGTH

The warranty on parts, materials and components extends five years from the date of installation on the original retail customer's home or location. This warranty extends to the first retail purchaser, and to any subsequent purchasers or owners at the same location during the warranty period. Any such transfer will not extend the 5-year duration of the warranty. If warranty service causes an extended period of system nonperformance, the warranty will be extended by the period of time the system did not perform.

9.5 WHAT IS NOT COVERED

- Damage due to owner's unauthorized attempts to repair the products, inappropriate parts substitution, neglect, misuse, abnormal weather conditions and electric power failures.
- Conditions arising from a defect in a component which is not part of the system.
- Products which are not installed and maintained in accordance with the installation, operation and maintenance instructions, and/or applicable ordinances and codes.
- Consequential damage to your home, inconvenience, loss of time, or loss of the use of your solar system as a result of system malfunction.
- Normal fading and minor deterioration of exterior surfaces resulting from exposure to the elements, except conditions that do or will affect performance.
- Glass or plastic glazing breakage from any cause.

9.6 OTHER RIGHTS AND REMEDIES

NO OTHER EXPRESS WARRANTIES

The entire obligation of Butler Sun Solutions regarding its solar system is stated within this warranty. Butler Sun Solutions does not authorize its representatives or any other person to make any other warranties or assume for it any other liabilities in connection with the sale of its products.

FURTHER, THERE ARE NO WARRANTIES THAT ARE NOT STATED HEREIN.

IMPLIED WARRANTIES

This warranty gives you specific legal rights, and you may also have other rights which vary from state to state, including in California, implied warranties or merchantability and, in certain instances, of fitness for particular purpose.

LIMITS OF LIABILITY

The customer agrees that Butler Sun Solutions liability for any warranty issue is expressly limited to the amount paid by the customer for the Butler Sun Solutions solar system, and if Butler Sun Solutions pays this amount, it has the right to remove the system from the customers' premises.

RIGHTS TO ARBITRATION

Any dispute between the buyer and Butler Sun Solutions pertaining to the warranty may at the option of the buyer or seller, be resolved by arbitration in California according to the rules of the American Arbitration Association.

10.0 System Specifications

Self Pressurized Closed Loop	1 Gallon of Antifreeze
Antifreeze	50% Propylene Glycol-50% Water by Volume
Toxicity	Gosselin Rating below One
AWWA Class II	Objectionable, but not dangerous to health.
Min. Operating Temp.	-32^{o}C (-26^{o}F)
Max. Operating Temp.	124^{o}C (256^{o}F)
Pressure Range	-2 to 16 psig
Pump	
Motor	Brushless DC
Seals	Seal-less leak-proof
Motor to PV panel	Linear Current Amplifier External/Built In
PV panel size	
El-SID	15 Watt DC Peak Rated, 1”x 12” x 48”
Laing D4 or D5	20 Watt DC Peak Rated, 1”x 18” x 36”
Backflow Prevention	Laing Pump Built In or Separate Check Valve
Materials	Brass & Stainless Steel
Controls	
Pump On/Off	Sun on PV Panel or Delta-T Controller
Tank Top High Limit	140^{o}F -180^{o}F Snap Switch or Thermistor
Umbilical from Collectors to Tank	
Length	25 Feet Standard
Maximum Length	150 Feet maximum recommended
Fluid Tubes	Two 3/8” Copper Refrigeration Tubes (.032” Wall), Spaced 1/8” apart
Fluid Tubing Spacers	Every 6” to 10” along the length
Insulation	½” Wall Closed Cell Rubber Foam (Rubitex^{tm}, Armacel^{tm})
Electrical Cable	3 Conductor AWG 18 , Outdoor Cable
UV Protection	2” ABS Spit Pipe and Elbows
Solar Wand Heat Exchanger	
Type	Double-Walled, Protected (AWWA-DWP)
Wall Material	.032 inch Thick Copper Walls
Protection	No leak of Propylene Glycol into Drinking Water
Failure Indicator	Tell Tale Appearance of Water or Glycol near top of Wand Outside of the Water Tank
Placement	Threads Into ¾-FNPT or 1-FNPT Hot Outlet of Water Tank
Lengths	Wands 46”and 36” Tank Inside Bottom to Top of Outlet Threads 46-1/2”, 36-1/2”
Removable	Can be Transferred to New Hot Water Tank
Heat Exchanger Area	2 Sq. Ft. and 1.6 Sq. Ft.
Connection to Solar Loop	3/8” Copper Tube Compression Fittings Both Inlet & Outlet
Normal Fluid Loop Temp.	180^{o}F -210^{o}F

Heat Ex. Delt-T Peak	18°F (10°C)
Morning Heat up Rate	108°F (60°C) in 10 minutes @350W/m^2
Fluid Flow Rate	0.5 Gallons per Min., 4 Pounds per Min.
BTU Output at Peak	4,320 BTU per Hour
Material	Copper
Fluid Temperature-Pressure-Air Elimination System	
Temperature Limit	Steam to Air Radiator (124°C (256°F))
Pressure Limit	16 psig
Vacuum Limit	-2 psig
Air Expulsion Heat Up	Trapped Air Bubbles Through Overflow Reservoir.
Liquid Backfill Cool Down	Liquid Drawn into Closed loop from the Bottom of Overflow Reservoir.
Reservoir Maintenance	Fluid Level Gauge Turns On Add Fluid Light on Top of Water Tank.
Valves for Isolation & Filling	
Fill	¼" Tube valve
Drain	¼" Tube valve
Isolation Valve Wand Inlet	¼ -Turn Ball Valve
Pump Isolation Valve	¼ -Turn Ball Valve, Between Fill and Drain Valves
Backflow Prevention Valve	Pressure Open, Between Fill and Drain Valves
Solar Water Storage Tank	
Retrofit to Existing Tank	40 to 60 Gallons
New Installation	75-100 Gallons
Second Solar Preheat Tank	60-80 Gallons
Anti- Scald Valve	Set at 120°F (49°C)
Solar Collector Modules (Manufactured by ACR for Butler Sun Solutions)	
Modules Required	Four (40 Sq. Ft.) to Eight (80 Sq. Ft.)
Module Shipping	4 per Package, FedEx or UPS Ground
Module Area	10 Sq. Ft
Module Dimensions	20"x72"x3"
Module Weight	20 Lbs.
Absorber Plate	Thermafin copper with Black Chrome Selective Absorber
Flow Path	Serpentine from Headers
Glazing	Double Wall, UV Inhibited, Polycarbonate
Insulation	Polyisocyanurate, Foil faced
Housing	Aluminum Sheet Metal
Dimension for Four Collector Module Arrays	
Single Column	80" Tall x 72" Wide
Single Row	20" Tall x 291" Wide
Two High by Two Wide	40" Tall x 145" Wide
Alternative Solar Collector Suppliers	
Sun Earth Flat Plates	Empire EC-EP-32 Selective Absorber, AR Glass Empire EC-EP-40 Selective Absorber, AR Glass
Thermomax Evac. Tubes	SolaMax Flow in Fin

	Mazdon Heat Pipe
Sunda Evac. Tubes	Heat Pipe
Apercus Evac. Tubes	Heat Pipe

Filling Procedure

Flushing	City Water Pressure
Filling	
Gravity	Siphon In Antifreeze From Filler Neck on Roof
Pump Manual/Electric	Pump Loop and Fill Overflow

System Performance in San Diego, CA

Energy Produced per Year	14.227 MBTU
	2,862 kWh
	155 Gallons of Propane
System Performance	950 BTU/ Ft^2/ day (2.8kWh/m^2/day)
Latitude Tilt Insolation	1,947 BTU/ Ft^2/day (5.7kWh/m^2/day)
System Annual Efficiency	35-48% for 50 & 80 gallon tanks respectively
Solar Hot Water Daily	About 40 Gallons/Day
Hot Water Needs	About 65 Gallons/Day for a Family of 4
Solar Fraction	About 60% Provided by Solar

Maintenance

Operation	Check Temperature Gauge Any Sunny Day
Fluid Level	Check Add Fluid Light, 4 Months to Dry
Fluid Fill	
Roof	Fill Overflow Reservoir from Float Cap
Water Tank	Pump Fluid into System to Fill Overflow

11.0 APPENDIX 1. SOLAR HOT TUB

The solar heated hot tubs have become more popular and will be included in full as a part of Revision 6. We have included some materials is this appendix that will help those who are considering hot tub systems. A typical hot tub installation is shown in **Figure A-1.**

Figure A-1 Hot Tub Showing Umbilical Coming Down Wall and Into Hot Tub.

The hot tub single wall heat exchanger is shown in **Figure A-2** with the large plastic inlet and outlets and the copper fluid loop inlet and outlet. Note the warning to keep the pH neutral, failure to do so will dramatically shorten the life of the replaceable copper heat exchanger.

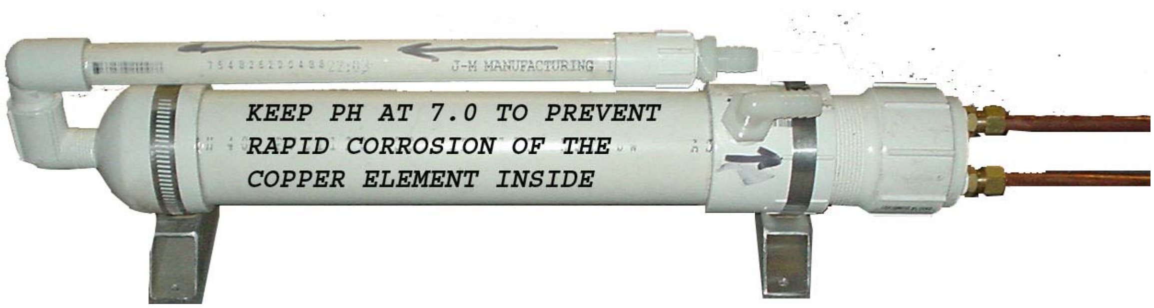


Figure A-2 Single Wall Solar Hot Tub Heat Exchanger

The Schematic of the hot tub system is shown in **Figure A-3**. The solar collectors and other working parts of the fluid loop are the same as for the solar hot water system. The new components are a heat exchanger, an adjustable thermostat and a spa side circulating pump, if your spa does not have the circulator run all of the time. The thermostat is a bulb type, with a temperature adjustment to limit the spa temperature to 104^{o}F.

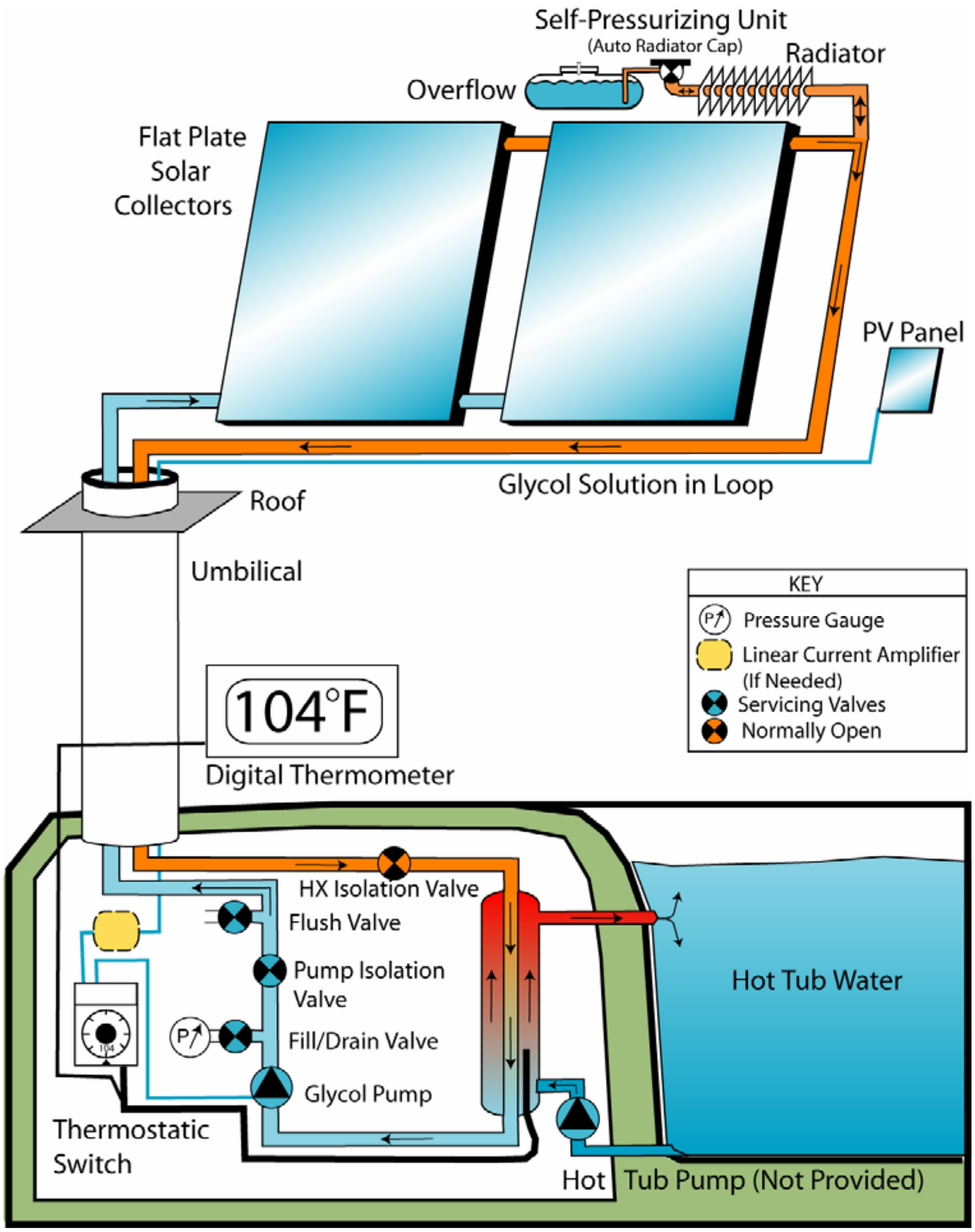


Figure A-3 Hot Tub System Schematic